REPORT

OF THE

THIRTY-THIRD MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

NEWCASTLE-UPON-TYNE IN AUGUST AND SEPTEMBER 1863.

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Page 95, line 3 of note, *for* was very faint *read* is very faint.
,, 96, line 18, *for* so far as *read* as far as.
,, 97, 5th line of par. 8, *for* states *read* state.
,, 100, line 12, *for* takes *read* take.
,, ,, last line of note, *for* Phil. Mag. xxiv. 2. *read* Phil. Mag. xxiv. p. 2.
,, 101, line 20, *for* colouring-matter or its combustion *read* colouring-matter and its combustion.
,, ,, in note **, 6th line from bottom of page, *for* Mr. Wedgwood *read* Th. Wedgwood.
,, 103, line 12, *for* were *read* was.
,, 339, middle of page, for *Fourth Report* read *Fifth Report*.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another, and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee, shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

1. Presidents and Officers for the present and preceding years, with authors of Reports in the Transactions of the Association.

2. Members who have communicated any Paper to a Philosophical Society, which has been printed in its Transactions, and which relates to such subjects as are taken into consideration at the Sectional Meetings of the Association.

3. Office-bearers for the time being, or Delegates, altogether not exceeding three in number, from any Philosophical Society publishing Transactions.

4. Office-bearers for the time being, or Delegates, not exceeding three, from Philosophical Institutions established in the place of Meeting, or in any place where the Association has formerly met.

5. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing for the Meeting of the year by the President and General Secretaries.

6. The Presidents, Vice-Presidents, and Secretaries of the Sections are *ex-officio* members of the General Committee for the time being.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee, unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer, shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews EDINBURGH, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT .. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen. Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen.	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. .. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. .... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely. The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle. Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, BART., M.A., D.C.L., F.R.S... BATH, September 14, 1864.	The Lord Portman The Marquis of Bath The Lord Nelson William Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. Arthur Way, Esq., M.P. F. H. Dickinson, Esq. William Saunders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

THE GENERAL TREASURER'S ACCOUNT from 4th October 1862 (commencement of CAMBRIDGE MEETING) to 26th August 1863 (at NEWCASTLE-ON-TYNE).

RECEIPTS.

	£	s.	d.
To Balance brought on from last Account	394	7	9
Received Life Compositions at Cambridge and since	187	10	0
" Annual Subscriptions, ditto ditto	381	0	0
" Associates' Tickets, ditto ditto	432	0	0
" Ladies' Tickets, ditto ditto	242	0	0
" Sale of Consols	1374	7	6
" Dividends on Stock	246	10	1
" from the Sale of Publications—viz. Reports, Catalogues of Stars, &c.	51	17	7
" Balance of Grant made in 1861, for Photographic Pictures of the Sun, returned by Mr. Stewart	12	17	0
	£3322	9	11

PAYMENTS.

				£	s.	d.
By paid Expenses of Cambridge Meeting, Sundry Printing, Binding, Advertising, and Incidental Petty Expenses by the General Treasurer and the Local Treasurers				310	6	2
Paid for Printing, Engraving, and Binding Report of 31st Meeting				636	19	7
Salaries, 12 months				350	0	0
For Preparing Index to Reports				100	0	0
On account of Grants made at Cambridge Meeting, viz.—						
For Maintaining Establishment of Kew Observatory	£600	0	0			
Balloon Committee deficiency	70	0	0			
Balloon Ascents (other expenses)	25	0	0			
Entozoa	25	0	0			
Coal-fossils	20	0	0			
Herrings	20	0	0			
Granites of Donegal	5	0	0			
Prison Diet, &c.	20	0	0			
Vertical Atmospheric Movements	13	0	0			
Dredging Shetland	50	0	0			
Dredging North-east coast of Scotland	25	0	0			
Dredging Northumberland and Durham	17	3	10			
Dredging Committee superintendence	10	0	0			
Steamship Performance	100	0	0			
Balloon Committee	200	0	0			
Carbon under pressure	10	0	0			
Volcanic Temperature	100	0	0			
Bromide of Ammonium	8	0	0			
Electrical Standards	100	0	0			
Ditto, Construction and distribution	40	0	0			
Luminous Meteors	17	0	0			
Kew Additional Buildings for Photoheliograph	100	0	0			
Thermo-Electricity	15	0	0			
Analysis of Rocks	8	0	0			
Hydroids	10	0	0			
				1608	3	10
Balance at Bankers	£310	10	6			
Ditto in General Treasurer and Local Treasurers' hands	6	9	10			
				317	0	4
				£3322	9	11

II. Table showing the Names of Members of the British Association who have served on the Council in former years.

Aberdeen, Earl of, LL.D., K.G., K.T., F.R.S. (deceased).
Acland, Sir Thomas D., Bart., M.A., D.C.L., F.R.S.
Acland, Professor H. W., M.D., F.R.S.
Adams, Prof. J. Couch, M.A., D.C.L., F.R.S.
Adamson, John, Esq., F.L.S.
Ainslie, Rev. Gilbert, D.D., Master of Pembroke Hall, Cambridge.
Airy, G. B., M.A., D.C.L., F.R.S., Astronomer Royal.
Alison, Professor W. P., M.D., F.R.S.E. (dec^d).
Allen, W. J. C., Esq.
Anderson, Prof. Thomas, M.D.
Ansted, Professor D. T., M.A., F.R.S.
Argyll, George Douglas, Duke of, F.R.S. L. & E.
Armstrong, Sir W. G., F.R.S.
Arnott, Neil, M.D., F.R.S.
Ashburton, William Bingham, Lord, D.C.L.
Atkinson, Rt. Hon. R., late Lord Mayor of Dublin.
Babbage, Charles, Esq., M.A., F.R.S.
Babington, Professor C. C., M.A., F.R.S.
Baily, Francis, Esq., F.R.S. (deceased).
Baines, Rt. Hon. M. T., M.A., M.P. (dec^d).
Baker, Thomas Barwick Lloyd, Esq.
Balfour, Professor John H., M.D., F.R.S.
Barker, George, Esq., F.R.S. (deceased).
Beamish, Richard, Esq., F.R.S.
Beechey, Rear-Admiral, F.R.S. (deceased).
Bell, Isaac Lowthian, Esq.
Bell, Professor Thomas, V.P.L.S., F.R.S.
Bengough, George, Esq.
Bentham, George, Esq., Pres.L.S.
Biddell, George Arthur, Esq.
Bigge, Charles, Esq.
Blakiston, Peyton, M.D., F.R.S.
Boileau, Sir John P., Bart., F.R.S.
Boyle, Right Hon. D., Lord Justice-General (deceased).
Brady, The Rt. Hon. Maziere, M.R.I.A., Lord Chancellor of Ireland.
Brand, William, Esq.
Breadalbane, John, Marquis of, K.T., F.R.S. (deceased).
Brewster, Sir David, K.H., D.C.L., LL.D., F.R.S. L. & E., Principal of the University of Edinburgh.
Brisbane, General Sir Thomas M., Bart., K.C.B., G.C.H., D.C.L., F.R.S. (dec^d).
Brodie, Sir B. C., Bart., D.C.L., V.P.R.S. (deceased).
Brooke, Charles, B.A., F.R.S.
Brown, Robert, D.C.L., F.R.S. (deceased).
Brunel, Sir M. I., F.R.S. (deceased).
Buckland, Very Rev. William, D.D., F.R.S., Dean of Westminster (deceased).
Bute, John, Marquis of, K.T. (deceased).
Carlisle, George Will. Fred., Earl of, F.R.S.
Carson, Rev. Joseph, F.T.C.D.
Cathcart, Lt.-Gen., Earl of, K.C.B., F.R.S.E. (deceased).
Challis, Rev. J., M.A., F.R.S.
Chalmers, Rev. T., D.D. (deceased).
Chance, James, Esq.
Chester, John Graham, D.D., Lord Bishop of.
Chevallier, Rev. Temple, B.D., F.R.A.S.
Christie, Professor S. H., M.A., F.R.S.
Clapham, R. C., Esq.
Clare, Peter, Esq., F.R.A.S. (deceased).
Clark, Rev. Prof., M.D., F.R.S. (Cambridge.)
Clark, Henry, M.D.
Clark, G. T., Esq.
Clear, William, Esq. (deceased).
Clerke, Major S., K.H., R.E., F.R.S. (dec^d).
Clift, William, Esq., F.R.S. (deceased).
Close, Very Rev. F., M.A., Dean of Carlisle.
Cobbold, John Chevalier, Esq., M.P.
Colquhoun, J. C., Esq., M.P. (deceased).
Conybeare, Very Rev. W. D., Dean of Llandaff (deceased).
Cooper, Sir Henry, M.D.
Corrie, John, Esq., F.R.S. (deceased)
Crum, Walter, Esq., F.R.S.
Currie, William Wallace, Esq. (deceased).
Dalton, John, D.C.L., F.R.S. (deceased).
Daniell, Professor J. F., F.R.S. (deceased).
Darbishire, R. D., Esq., B.A., F.G.S.
Dartmouth, William, Earl of, D.C.L., F.R.S.
Darwin, Charles, Esq., M.A., F.R.S.
Daubeny, Prof. C. G. B., M.D., LL.D., F.R.S.
DelaBeche, Sir H. T., C.B., F.R.S., Director-Gen. Geol. Surv. United Kingdom (dec^d).
De la Rue, Warren, Ph.D., F.R.S.
Derby, Earl of, D.C.L., Chancellor of the University of Oxford.
Devonshire, William, Duke of, M.A., D.C.L., F.R.S.
Dickinson, Joseph, M.D., F.R.S.
Dillwyn, Lewis W., Esq., F.R.S. (deceased).
Donkin, Professor W. F., M.A., F.R.S.
Drinkwater, J. E., Esq. (deceased).
Ducie, The Earl of, F.R.S.
Dunraven, The Earl of, F.R.S.
Egerton, Sir P. de M. Grey, Bart., M.P., F.R.S.
Eliot, Lord, M.P.
Ellesmere, Francis, Earl of, F.G.S. (dec^d).
Enniskillen, William, Earl of, D.C.L., F.R.S.
Estcourt, T. G. B., D.C.L. (deceased).
Fairbairn, William, LL.D., C.E., F.R.S.
Faraday, Professor, D.C.L., F.R.S.
Ferrers, Rev. N. M., M.A.
FitzRoy, Rear-Admiral, F.R.S.
Fitzwilliam, The Earl, D.C.L., F.R.S. (dec^d).
Fleming, W., M.D.
Fletcher, Bell, M.D.
Foote, Lundy E., Esq.
Forbes, Charles, Esq. (deceased).
Forbes, Prof. Edward, F.R.S. (deceased).
Forbes, Prof. J. D., LL.D., F.R.S., Sec. R.S.E. Principal of the University of St. Andrews.
Fox, Robert Were, Esq., F.R.S.
Frost, Charles, F.S.A.
Fuller, Professor, M.A.
Galton, Francis, F.R.S., F.G.S.

Gassiot, John P., Esq., F.R.S.
Gilbert, Davies, D.C.L., F.R.S. (deceased).
Gladstone, J. H., Ph.D., F.R.S.
Goodwin, The Very Rev. H., D.D., Dean of Ely.
Gourlie, William, Esq. (deceased).
Graham, T., M.A., D.C.L., F.R.S., Master of the Mint.
Gray, John E., Esq., Ph.D., F.R.S.
Gray, Jonathan, Esq. (deceased).
Gray, William, Esq., F.G.S.
Green, Prof. Joseph Henry, D.C.L., F.R.S. (deceased).
Greenough, G. B., Esq., F.R.S. (deceased).
Griffith, George, M.A., F.C.S.
Griffith, Sir R. Griffith, Bt., LL.D., M.R.I.A.
Grove, W. R., Esq., M.A., F.R.S.
Hallam, Henry, Esq., M.A., F.R.S. (decd).
Hamilton, W. J., Esq., F.R.S., Sec. G.S.
Hamilton, Sir Wm. R., LL.D., Astronomer Royal of Ireland, M.R.I.A., F.R.A.S.
Hancock, W. Neilson, LL.D.
Harcourt, Rev. Wm. Vernon, M.A., F.R.S.
Hardwicke, Charles Philip, Earl of, F.R.S.
Harford, J. S., D.C.L., F.R.S.
Harris, Sir W. Snow, F.R.S.
Harrowby, The Earl of, F.R.S.
Hatfeild, William, Esq., F.G.S. (deceased).
Henry, W. C., M.D., F.R.S.
Henry, Rev. P. S., D.D., President of Queen's College, Belfast.
Henslow, Rev. Professor, M.A., F.L.S. (decd).
Herbert, Hon. and Very Rev. Wm., LL.D., F.L.S., Dean of Manchester (decd).
Herschel, Sir John F.W., Bart., M.A., D.C.L., F.R.S.
Heywood, Sir Benjamin, Bart., F.R.S.
Heywood, James, Esq., F.R.S.
Hill, Rev. Edward, M.A., F.G.S.
Hincks, Rev. Edward, D.D., M.R.I.A.
Hincks, Rev. Thomas, B.A.
Hinds, S., D.D., late Lord Bishop of Norwich (deceased).
Hodgkin, Thomas, M.D.
Hodgkinson, Professor Eaton, F.R.S. (decd).
Hodgson, Joseph, Esq., F.R.S.
Hooker, Sir William J., LL.D., F.R.S.
Hope, Rev. F. W., M.A., F.R.S.
Hopkins, William, Esq., M.A., LL.D., F.R.S.
Horner, Leonard, Esq., F.R.S. (deceased).
Houghton, Lord, D.C.L.
Hovenden, V. F., Esq., M.A.
Hugall, J. W., Esq.
Hunt, Aug. H., Esq., B.A., Ph.D.
Hutton, Robert, Esq., F.G.S.
Hutton, William, Esq., F.G.S. (deceased).
Ibbetson, Capt. L. L. Boscawen, K.R.E., F.G.S.
Inglis, Sir R. H., Bart., D.C.L., M.P. (decd).
Inman, Thomas, M.D.
Jacobs, Bethel, Esq.
Jameson, Professor R., F.R.S. (deceased).
Jardine, Sir William, Bart., F.R.S.E.
Jeffreys, John Gwyn, Esq., F.R.S.
Jellett, Rev. Professor.
Jenyns, Rev. Leonard, F.L.S.
Jerrard, H. B., Esq.
Jeune, The Right Rev. F., D.C.L.
Johnston, Right Hon. William, late Lord Provost of Edinburgh.
Johnston, Prof. J. F. W., M.A., F.R.S. (deceased).
Keleher, William, Esq. (deceased).
Kelland, Rev. Prof. P., M.A., F.R.S. L. & E.
Kildare, The Marquis of.
Lankester, Edwin, M.D., F.R.S.
Lansdowne, Hen., Marquis of, D.C.L., F.R.S.
Larcom, Major, R.E., LL.D., F.R.S.
Lardner, Rev. Dr. (deceased).
Lassell, William, Esq., F.R.S. L. & E.
Latham, R. G., M.D., F.R.S.
Lee, Very Rev. John, D.D., F.R.S.E., Principal of the University of Edinburgh (deceased).
Lee, Robert, M.D., F.R.S.
Lefevre, Right Hon. Charles Shaw, late Speaker of the House of Commons.
Lemon, Sir Charles, Bart., F.R.S.
Liddell, Andrew, Esq. (deceased).
Liddell, Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
Lindley, Professor John, Ph.D., F.R.S.
Listowel, The Earl of.
Liveing, Prof. G. D., M.A., F.C.S.
Lloyd, Rev. B., D.D., Provost of Trin. Coll., Dublin (deceased).
Lloyd, Rev. H., D.D., D.C.L., F.R.S. L. & E., M.R.I.A.
Londesborough, Lord, F.R.S. (deceased).
Lubbock, Sir John W., Bart., M.A., F.R.S.
Luby, Rev. Thomas.
Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S.
MacCullagh, Prof., D.C.L., M.R.I.A. (decd).
MacDonnell, Rev. R., D.D., M.R.I.A., Provost of Trinity College, Dublin.
Macfarlane, The Very Rev. Principal. (decd).
MacGee, William, M.D.
MacLeay, William Sharp, Esq., F.L.S.
MacNeill, Professor Sir John, F.R.S.
Malahide, The Lord Talbot de.
Malcolm, Vice-Ad. Sir Charles, K.C.B. (decd).
Maltby, Edward, D.D., F.R.S., late Lord Bishop of Durham (deceased).
Manchester, J. P. Lee, D.D., Lord Bishop of.
Marlborough, Duke of, D.C.L.
Marshall, J. G., Esq., M.A., F.G.S.
May, Charles, Esq., F.R.A.S. (deceased).
Meynell, Thomas, Esq., F.L.S.
Middleton, Sir William F. F., Bart.
Miller, Professor W. A., M.D., Treas. and V.P.R.S.
Miller, Professor W. H., M.A., For. Sec. R.S.
Moggridge, Matthew, Esq.
Moillet, J. D., Esq. (deceased).
Monteagle, Lord, F.R.S.
Moody, J. Sadleir, Esq.
Moody, T. H. C., Esq.
Moody, T. F., Esq.
Morley, The Earl of.
Moseley, Rev. Henry, M.A., F.R.S.
Mount-Edgecumbe, Ernest Augustus, Earl of.
Murchison, Sir Roderick I., G.C. St.S., D.C.L., LL.D., F.R.S.
Neild, Alfred, Esq.

Neill, Patrick, M.D., F.R.S.E.
Nicol, D., M.D.
Nicol, Professor J., F.R.S.E., F.G.S.
Nicol, Rev. J. P., LL.D.
Noble, Capt. A., R.A.
Northampton, Spencer Joshua Alwyne, Marquis of, V.P.R.S. (deceased).
Northumberland, Hugh, Duke of, K.G., M.A., F.R.S. (deceased).
Ormerod, G. W., Esq., M.A., F.G.S.
Orpen, Thomas Herbert, M.D. (deceased).
Orpen, John H., LL.D.
Osler, Follett, Esq., F.R.S.
Owen, Professor Richd., M.D., D.C.L., LL.D., F.R.S.
Oxford, Samuel Wilberforce, D.D., Lord Bishop of, F.R.S., F.G.S.
Palmerston, Viscount, K.G., G.C.B., M.P., F.R.S.
Peacock, Very Rev. G., D.D., Dean of Ely, F.R.S. (deceased).
Peel, Rt. Hon. Sir R., Bart., M.P., D.C.L. (dec[d]).
Pendarves, E. W., Esq., F.R.S. (deceased).
Phillips, Professor John, M.A., LL.D., F.R.S.
Phillips, Rev. G., B.D., President of Queen's College, Cambridge.
Pigott, The Rt. Hon. D. R., M.R.I.A., Lord Chief Baron of the Exchequer in Ireland.
Porter, G. R., Esq. (deceased).
Portlock, Major-General, R.E., LL.D., F.R.S.
Powell, Rev. Professor, M.A., F.R.S. (dec[d]).
Price, Rev. Professor, M.A., F.R.S.
Prichard, J. C., M.D., F.R.S. (deceased).
Ramsay, Professor William, M.A.
Ransome, George, Esq., F.L.S.
Reid, Maj.-Gen. Sir W., K.C.B., R.E., F.R.S. (deceased).
Rendlesham, Rt. Hon. Lord, M.P.
Rennie, George, Esq., F.R.S.
Rennie, Sir John, F.R.S.
Richardson, Sir John, C.B., M.D., LL.D., F.R.S.
Richmond, Duke of, K.G., F.R.S. (dec[d]).
Ripon, Earl of, F.R.G.S.
Ritchie, Rev. Prof., LL.D., F.R.S. (dec[d]).
Robinson, Capt., R.A.
Robinson, Rev. J., D.D.
Robinson, Rev. T. R., D.D., F.R.S., F.R.A.S.
Robison, Sir John, Sec.R.S.Edin. (deceased).
Roche, James, Esq.
Roget, Peter Mark, M.D., F.R.S.
Rolleston, Professor, M.D., F.R.S.
Ronalds, Francis, F.R.S. (deceased).
Roscoe, Professor H. E., B.A., F.R.S.
Rosebery, The Earl of, K.T., D.C.L., F.R.S.
Ross, Rear-Admiral Sir J. C., R.N., D.C.L., F.R.S. (deceased).
Rosse, Wm., Earl of, M.A., F.R.S., M.R.I.A.
Royle, Prof. John F., M.D., F.R.S. (dec[d]).
Russell, James, Esq. (deceased).
Russell, J. Scott, Esq., F.R.S.
Sabine, Major-General Edward, R.A., D.C.L., LL.D., President of the Royal Society.
Sanders, William, Esq., F.R.S., F.G.S.
Scoresby, Rev. W., D.D., F.R.S. (deceased).
Sedgwick, Rev. Prof. Adam, M.A., D.C.L., F.R.S.
Selby, Prideaux John, Esq., F.R.S.E.
Sharpey, Professor, M.D., Sec.R.S.
Sims, Dillwyn, Esq.
Smith, Lieut.-Colonel C. Hamilton, F.R.S. (deceased).
Smith, Prof. H. J. S., M.A., F.R.S.
Smith, James, F.R.S. L. & E.
Spence, William, Esq., F.R.S. (deceased).
Spottiswoode, W., M.A., F.R.S.
Stanley, Edward, D.D., F.R.S., late Lord Bishop of Norwich (deceased).
Staunton, Sir G. T., Bt., M.P., D.C.L., F.R.S.
St. David's, C. Thirlwall, D.D., Lord Bishop of.
Stevelly, Professor John, LL.D.
Stokes, Professor G. G., M.A., D.C.L., Sec.R.S.
Strang, John, Esq., LL.D.
Strickland, Hugh E., Esq., F.R.S. (deceased).
Sykes, Colonel W. H., M.P., F.R.S.
Symonds, B. P., D.D., Warden of Wadham College, Oxford.
Talbot, W. H. Fox, Esq., M.A., F.R.S.
Tayler, Rev. John James, B.A.
Taylor, Hugh, Esq.
Taylor, John, Esq., F.R.S. (deceased).
Taylor, Richard, Esq., F.G.S.
Thompson, William, Esq., F.L.S. (deceased).
Thomson, A., Esq.
Thomson, Professor William, M.A., F.R.S.
Tindal, Captain, R.N. (deceased).
Tite, William, Esq., M.P., F.R.S.
Tod, James, Esq., F.R.S.E.
Tooke, Thomas, F.R.S. (deceased).
Traill, J. S., M.D. (deceased).
Trevelyan, Sir W. C., Bart.
Turner, Edward, M.D., F.R.S. (deceased).
Turner, Samuel, Esq., F.R.S., F.G.S. (dec[d]).
Turner, Rev. W.
Tyndall, Professor John, F.R.S.
Vigors, N. A., D.C.L., F.L.S. (deceased).
Vivian, J. H., M.P., F.R.S. (deceased).
Walker, James, Esq., F.R.S.
Walker, Joseph N., Esq., F.G.S.
Walker, Rev. Professor Robert, M.A., F.R.S.
Warburton, Henry, Esq., M.A., F.R.S. (dec[d]).
Ward, W. Sykes, Esq., F.C.S.
Washington, Captain, R.N., F.R.S.
Webster, Thomas, M.A., F.R.S.
West, William, Esq., F.R.S. (deceased).
Western, Thomas Burch, Esq.
Wharncliffe, John Stuart, Lord, F.R.S. (dec[d]).
Wheatstone, Professor Charles, F.R.S.
Whewell, Rev. William, D.D., F.R.S., Master of Trinity College, Cambridge.
White, John F., Esq.
Williams, Prof. Charles J. B., M.D., F.R.S.
Willis, Rev. Professor Robert, M.A., F.R.S.
Wills, William, Esq., F.G.S. (deceased).
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Wilson, Prof. W. P.
Winchester, John, Marquis of.
Wood, Nicholas, Esq.
Woollcombe, Henry, Esq., F.S.A. (deceased).
Wrottesley, John, Lord, M.A., D.C.L., F.R.S.
Yarborough, The Earl of, D.C.L.
Yarrell, William, Esq., F.L.S. (deceased).
Yates, James, Esq., M.A., F.R.S.
Yates, J. B., Esq., F.S.A., F.R.G.S. (dec[d]).

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Professor Adolph Steen, *Copenhagen.*
Dr. Otto Torell, *University of Lund.*

Report of the Council of the British Association, presented to the General Committee, Wednesday, August 26, 1863.

1. The Report of the Kew Committee has been presented at each of the Meetings of the Council, and the General Report for the year 1862–63 has been received, and is now presented to the General Committee.

2. The Report of the Parliamentary Committee has been received for presentation to the General Committee this day.

3. It will be in the recollection of the General Committee that at the Cambridge Meeting, when Professor Phillips resigned the office of Assistant-General Secretary, which he had held from the beginning of the Association, he was prevailed upon to join Mr. Hopkins as Joint-General Secretary until the present Meeting. The attention of the Council was called to this arrangement on the 5th of June last by Professor Phillips, who, in claiming permission to retire from office, recommended that in filling this office permanently at the Newcastle Meeting, regard should be had to the advantage of having one of the General Secretaries resident in London.

On this a Committee was appointed, consisting of the General Secretaries, and the gentlemen who had formerly filled that office, for the purpose of reporting a recommendation to the Council of a successor to Professor Phillips. The Council have received the following Report:—

> "Professor Phillips, F.R.S., having kindly consented, at the request of the General Committee of the British Association, to hold, in conjunction with Mr. Hopkins, F.R.S., the office of General Secretary, and being now desirous of retiring from the office; We, the undersigned, having been requested by the Council to suggest a suitable successor to Professor Phillips, beg to express our unanimous opinion that Mr. Francis Galton, M.A., F.R.S., of Trinity College, Cambridge, is well qualified to fill the office of Joint-General Secretary of the Association.
>
> "W. V. Harcourt.
> "R. I. Murchison.
> "E. Sabine.
> "W. Hopkins.
> "J. Phillips."

4. The Council have been informed that invitations will be presented to the General Committee, at its Meeting on Monday, August 31st, from Birmingham, Bath, Nottingham, Dundee, Southampton, and the Potteries.

Report of the Kew Committee of the British Association for the Advancement of Science for 1862–1863.

The Committee of the Kew Observatory submit to the Association the following statement of their proceedings during the past year.

It was mentioned in last Report that the Director of the Lisbon Observatory had requested the Committee to superintend the construction of a set of Self-recording Magnetographs. This request has been complied with by the Committee, and a set of Self-recording Magnetographs have been constructed by Adie under their direction. These, along with a tabulating instrument by Gibson, have been verified at Kew, where Señor Capello, of the Lisbon Observatory, resided for some time, in order to become familiar with the working of his instruments.

This verification was completed in December last, and Señor Capello then left England for Lisbon, taking his instruments with him. These arrived safely at their destination; and so rapid was the progress made with the Observatory, that on the 1st of July the building was finished, and the Magnetographs in continuous operation.

Mr. Stewart has lately received from Señor Capello copies of the tracings furnished by these instruments from July 14th to 16th, during which period a magnetic disturbance occurred simultaneously at Lisbon and at Kew. These tracings, along with the corresponding Kew curves, are exhibited to the Association.

When the two sets are viewed side by side, features of resemblance become manifest, which appear to show that very great advantage to magnetical science will ultimately be derived from the intercomparison of such photographic traces taken simultaneously at different localities.

Mr. Stewart has likewise heard from Señor De Souza, of the University of Coimbra, who writes that, after many preliminary difficulties, his Observatory is now making rapid progress towards completion.

Before his departure from this country, Señor Capello addressed the following letter to the Chairman of the Kew Committee:—

"Kew Observatory, November 28, 1862.

"My dear Sir,—I should much desire to obtain for the Lisbon Observatory some memorial of my visit to Kew, where I have received much valuable instruction in Magnetism, as well as great kindness from yourself, from General Sabine, and from other Members of the Kew Committee.

"Might I request of you, dear Sir, to endeavour to obtain for me a set of the 'Transactions of the British Association,' wherewith to enrich our Library at Lisbon?

"Will you also at the same time kindly permit us to continue sending to your Library, as a slight token of our goodwill, the monthly records of our Observatory?

"I remain,
"Dear Sir,
"Yours sincerely,
(Signed) "J. C. Brito Capello."

"*J. P. Gassiot, Esq., F.R.S.,*
Chairman of the Kew Committee of the
British Association."

The request of this letter has been complied with by the Council of the Association, and a complete set of the 'Transactions' have been despatched to Lisbon.

The Committee have likewise been requested to superintend the construction of a set of Self-recording Magnetographs for Prof. Kupffer, of the St. Petersburg Central Observatory. These were constructed as before, the Magnetographs by Adie, and the tabulating instrument by Gibson; and, after having been verified at Kew, they were despatched to St. Petersburg.

Prof. Kupffer desired also a Differential Vertical-force Magnetometer for Pekin, which has likewise been constructed by Adie, and verified at Kew; it remains in readiness to be forwarded by the first suitable opportunity to its destination.

In addition to these instruments, Prof. Kupffer is obtaining from Adie a Barograph and a Self-registering Anemometer, both of the Kew pattern.

Prof. Kupffer proposes visiting Kew in October, for the purpose of acquainting himself with the mode of working the instruments adopted there.

It was mentioned in last Report that Lieut. Rokeby, of the Royal Marines, was desirous of making magnetical and meteorological observations in the Island of Ascension during his term of service at that station, and that the Board of Trade had sanctioned the expenditure of £60 to provide a suitable Observatory.

Lieut. Rokeby has since been zealously engaged with his observations, and has already transmitted the records to General Sabine.

In order to complete his meteorological equipment, a Self-recording Anemometer was necessary, and one of these on the Kew pattern has been constructed by Adie, and forwarded to Ascension, for the cost of which application has been made to the Government Grant Committee of the Royal Society.

It may be allowed to use this opportunity of stating, that already no fewer than nine Self-recording Anemometers on Beckley's or the Kew pattern have been made for different Observatories.

The Observatory of the McGill College at Montreal has been completed, and Dr. Smallwood writes that the absolute determination of the three magnetic elements and hourly observations of the Declinometer were to have been commenced there in July last.

The usual monthly absolute determinations of the magnetic elements continue to be made at Kew, and the Self-recording Magnetographs are in constant operation as heretofore, under the zealous superintendence of Mr. Chambers, the Magnetical Assistant.

Advantage has been taken of these automatic records of the earth's magnetism by the Committee engaged in the preparation of electrical standards, who have found it desirable for some of their experiments to ascertain the contemporaneous readings of the Declination Magnetograph.

The extensive use of iron in the construction of modern ships has rendered a careful determination of its effect upon ships' compasses essentially requisite to safe navigation. A demand has consequently arisen for the aid of persons who have made the subject one of special study, in order to make the observations that are most desirable, and to supply the required information, the process generally adopted being to swing the vessel round with her head towards the different points of the compass in succession. The needs of the Royal Navy in this respect are amply provided for; but hitherto Government has taken no steps towards extending the system adopted in that department to ships of the Mercantile Marine. On this account the Committee have much pleasure in reporting that Mr. Chambers has practically taken up the subject, and has obtained from the Director of the Observatory occasional leave of absence, when this shall be necessary, to enable him to attend at the swinging of ships. In this work his long experience of accurate and varied magnetic observations at Kew, and his familiar acquaintance with the "theory of deviations of the compass," must prove to be of great value; and the Committee desire to record their opinion that in thus affording to the observers at Kew an excellent training, which is capable of most useful application in the public service, the maintenance of the Observatory is shown to be attended with indirect advantages scarcely less important than the valuable results of observations which it is the more immediate province of the Observatory to secure.

Major-General Sabine, President of the Royal Society, has communicated to that body a paper on the "Results of the Magnetic Observations at the Kew

Observatory, from 1857 to 1862 inclusive." In this communication the following subjects are discussed:—

1. The disturbance-diurnal variation of the declination.
2. The solar-diurnal variation of the declination.
3. The semiannual inequality of the solar-diurnal variation of the declination.
4. The lunar-diurnal variation of the declination.
5. The secular change, and the annual variation of the declination, dip, and total force.

The values of these changes at Kew are compared with those at the different Colonial Magnetic Observatories, and results of much interest and importance are obtained.

A copy of this paper will be sent to each Member of the Committee of Recommendations of the Association as soon as it is out of the printer's hands.

At the request of the Astronomer Royal, the Kew curves of declination and horizontal force for 14th December last (a time of disturbance) were forwarded to Greenwich, in order that Mr. Airy might compare them with the records of earth-currents obtained there at the same date.

In return Mr. Airy kindly sent copies of these latter records to Kew, and a comparison of these with the indications afforded by the Kew Magnetographs forms the subject of a short communication by Mr. Stewart, which is published in the Proceedings of the Royal Society.

Mr. Stewart has likewise communicated to the Royal Society of Edinburgh a paper on "Earth Currents during Magnetic Calms, and their Connexion with Magnetic Changes," which is about to be published in the Transactions of that body. He has likewise communicated to the Royal Society of London an account of some experiments made at Kew, in order to determine the increase between 32° Fahr. and 212° Fahr. of the elasticity of dry atmospheric air, the volume of which remains constant, and also to determine the freezing-point of mercury.

This communication will be published in the Transactions of the Royal Society. The experiments were made by means of an air-thermometer, in the construction of which great assistance was derived from Mr. Beckley, Mechanical Assistant, while Mr. George Whipple, Meteorological Assistant, was of much use in observing.

Mr. Chambers has communicated to the Royal Society a paper "On the Nature of the Sun's Magnetic Action upon the Earth," in which it is argued that, in causing the daily variation, the sun does not act as a magnet.

The Meteorological work of the Observatory continues to be performed satisfactorily by Mr. George Whipple, and all the Staff interest themselves much in the business of the Observatory.

During the past year

130 Barometers,
296 Thermometers, and
22 Hydrometers

have been verified; and Mr. Kemp, philosophical instrument maker, Edinburgh, has been furnished with a standard Thermometer.

The self-recording Barograph has been in constant operation since 8th November last. A suggestion by Mr. Beckley to put two papers at the same time upon the cylinder, the one under the other, has proved successful; and two traces have thus been secured, one of which has been regularly forwarded

to Admiral FitzRoy, at his request, while the other has been retained at the Observatory.

On 30th December, the Superintendent received the following letter from Admiral FitzRoy:—

"Meteorological Department, 2 Parliament Street, London, 30th December, 1862.

"Sir,—I have the honour of addressing the Kew Committee of the British Association, through yourself, as Superintendent at their Magnetic and Meteorologic Observatory, to request, on behalf of the Board of Trade, that daily meteorologic communications may be again made to this Office, as formerly.

"Having extended our operations, and therefore incurred greater responsibility, it is considered advisable to acquire, if possible, the best strengthening support available.

"On account of economical reasons solely, as you are aware, the Board of Trade asked for discontinuance of those Kew telegrams (which were then received as regularly as satisfactorily); but now, being able to add their expense (comparatively small) to the current charges of this Office, it is my pleasing duty to make this application.

"The Kew Observatory *is so well situated* for Meteorologic purposes, because separated from all *local* causes of error—neither on a hill nor in a valley, surrounded by grass land, on a level only about 35 feet above the sea, and to *windward* of our extensive Metropolis during the greater part of the year—that a better locality for reference and intercomparison need not be desired.

"It is sufficiently far from London to be uninfluenced by its *heated air*, smoke, or other *peculiarities* of atmosphere (inseparable from such an area of fires, population, and *altered radiation*), while it is within an easy railway trip.

"But while such are the well-known exterior recommendations of the Kew Observatory for its *specialities* of Magnetism and Meteorology, there are sterling advantages obtainable within its walls not to be found elsewhere. Scrupulously careful, exact, and truly-principled observations (inseparably connected with the names of Ronalds and Welsh) gave character and initiated proceedings of which results are now patent—not only in improvements of many kinds, affecting instruments and methods, but in *general* instruction.

"Nowhere else is there a *Cathetometer* by which barometric instruments can be perfectly *verified*. Other methods used elsewhere are inferior as to range, principle, and practice. To that instrument much more is due than may be yet generally recognized.

"Persons aware of these facts are naturally desirous that Kew should have a place in the reports now published daily in most of the newspapers, and as the Board of Trade will defray such small contingent expenses as may be requisite, I am led to believe that the Kew Committee will consent to the necessary steps, through your obliging attention.

"With this letter is a copy of the arrangements existing now, which are somewhat altered from those already known to yourself.

"It may be convenient to permit morning observations to be made, soon after eight, by a resident at the Observatory, and to employ a special messenger to carry them to the Telegraph Office, in order that we may receive them here early. The contingent charge would be borne by this Office.

"Lists of the places with which we now communicate, and forms for our daily Weather Reports, are enclosed—all which may help to show what im-

portance should be attached to the cooperation and prestige of the Kew Observatory.

"I have the honour to be,
"Sir,
"Your obedient Servant,
(Signed) "ROBT. FITZROY."

"*Balfour Stewart, Esq., F.R.S.,*
"*Superintending Kew Observatory.*"

In compliance with the request of this letter, telegrams were regularly furnished up to the end of May; but at that date the Superintendent received another letter from the Admiral, thanking the Observatory for the regularity and accuracy of its telegrams, but mentioning that, in consequence of two additional Foreign Stations being added to his list, there would not be space available for Kew, which really gave nearly the same indications as London. In consequence of this, telegrams were discontinued after the end of May.

The self-recording Electrometer of Prof. W. Thomson continues in constant operation.

The arrangements at the Observatory for testing Sextants remain as before without alteration, but it has been thought advisable to reduce the verification-fee from 5*s.* to 2*s.* 6*d.* for ordinary instruments, leaving that for an extremely accurate verification of a superior instrument the same as before.

Eleven sextants and one altitude and azimuth instrument have been verified at Kew since the last Meeting of the British Association.

The Chairman has procured a Spectroscope affording very great angular separation, which remains at Kew, and he has also ordered a Heliostat from Paris; by those means it is hoped that the minutiæ of the solar spectrum may soon be capable of being examined with great facility.

The solar spots are now regularly observed at Kew, after the method of Dr. Schwabe, of Dessau, who has been communicated with, and will be written to from time to time, in order to ensure that both observers pursue exactly the same method of observation.

It will be remembered that in the Report of the Committee at the Cambridge Meeting, it was stated that Mr. De la Rue had taken 177 photographs of the sun, and that the number of available days from February 7 to September 12, 1862, was 124. The Kew Heliograph was worked at Cranford up to February 7, 1863, and photographs were procured on 42 other days between Sept. 12, 1862, and February 7, 1863, making 166 working days in the whole year. The series of negatives are now in course of measurement and reduction by Dr. Von Bose; the micrometer employed is the same as that constructed for and used in the measurements of the eclipse-pictures obtained in Spain in 1860, a detailed description of which instrument is given in Mr. De la Rue's paper in the Phil. Trans. vol. clii. pp. 373 to 380.

Of the 1862–1863 series, the measurements are finished up to the end of June, and the reductions to the end of April 1862; both will be completed at the end of this year.

In February of the present year the Heliograph was removed from Cranford to the Kew Observatory, and erected again in the dome. A new and commodious photographic-room has been built on the roof of the Observatory, close to the dome, and has been fitted up with the requirements necessary for the successful prosecution of astronomical photography. The expense of this room has been defrayed out of the sum of £100 granted for that object at the

Accounts of the Kew Committee of the British Association from October 1, 1862 *to August* 26, 1863.

RECEIPTS.

	£	s.	d.	£	s.	d.
Received from the General Treasurer				600	0	0
„ for the verification of Instruments—						
from the Board of Trade	5	15	0			
from the Admiralty	15	5	0			
from Opticians	28	17	6			
„ for Barograph curves sent to the Meteorologic Office, London	16	14	3			
from the Portuguese Government for the verification of Magnetographs sent to the Lisbon Observatory	30	0	0			
„ for the construction of standard Thermometers	1	15	0			
				98	6	9
Balance				189	11	0
				£887	17	9

PAYMENTS.

	£	s.	d.	£	s.	d.
Balance from last account				182	2	6
Salaries, &c.:—						
To B. Stewart, four quarters, ending 1st October, 1863	200	0	0			
Ditto, allowed for petty travelling expenses	10	0	0			
C. Chambers, four quarters, ending 6th October, 1863	100	0	0			
Ditto, honorarium	10	0	0			
G. Whipple, four quarters, ending 18th September, 1863	60	0	0			
T. Baker, four quarters, ending 29th September, 1863	40	0	0			
R. Beckley, 47 weeks, ending 24th August, 1863, at 40*s*.	94	0	0			
				514	0	0
Apparatus, Materials, Tools, &c.				60	10	0
Ironmonger, Carpenter, and Mason				7	5	5
Printing, Stationery, Books, and Postage				31	16	9
Coals and Gas				49	9	5
House Expenses, Chandlery, &c.				15	3	0
Porterage and petty expenses				16	10	8
Rent of Land to 10th October, 1863				11	0	0
				£887	17	9

	£	s.	d.
I have examined the above account and compared it with the vouchers presented to me. I find that the amounts expended exceed those received by the sum of	7	8	6
To which must be added the excess of expenditure over income for the preceding years, as stated in the account of 17th September, 1862	182	2	6
Making the present balance of expenditure beyond receipts	£189	11	0

12*th August*, 1863.

R. HUTTON.

Cambridge Meeting. The actual sum expended up to the present time amounts to £89, leaving a balance of £11, which will cover the outlay for a few pieces of apparatus which are still required.

Between February 7 and May of the present year pictures of the sun were occasionally procured at Kew; but the Heliograph could not be fairly got to work until the completion of the photographic-room and the final adjustment of the instrument itself. From the 1st of May to the present time the Heliograph has been continuously worked by a qualified Assistant, under the immediate supervision of Mr. Beckley. Two photographs are taken on every working day, one to the east, and the other to the west of the meridian, when atmospheric conditions permit of this being done. From May 1st to August 14th inclusive, there have been fifty-four working days. Four positive copies are made regularly from each negative, one of which it is proposed to retain at Kew, and it is in contemplation to distribute the others.

Mr. Stewart, after an inspection of all the sun-pictures obtained by the Kew Heliograph, is inclined to think that the behaviour of solar spots with respect to increase and diminution has reference to ecliptical longitudes, and is possibly connected with the position of the nearer planets; but it will require a longer series of pictures to determine this, than that which has yet been obtained.

The Heliograph constructed by Mr. Dallmeyer for Wilna, under Mr. De la Rue's superintendence, has been completed, and will be shortly sent to Russia, together with a micrometer and protractor constructed by Messrs. Troughton and Simms, which will be employed in the measurement and reduction of the sun-pictures.

Of the £150 granted by the Association in 1861 for the purpose of obtaining a series of photographic pictures of the solar surface, a sum of £137 3*s.* has been expended from February 1862 to February 1863, and the balance, £12 17*s.*, has been returned to the Association.

In 1860 a sum of £90 was voted for an additional Photographic Assistant, of which £50 was received and expended in that year. The balance, £40, was again granted in 1861, out of which £20 2*s.* 10*d.* have been expended.

The working of the Kew Photoheliograph during the year, commencing in February 1863, will be defrayed out of a grant placed in the hands of Mr. De la Rue by the Royal Society for that purpose.

It will be seen from the Statement appended to this Report, that the expenditure of the Observatory has exceeded its income by £7 8*s.* 6*d.*; but there is £30 to be received from the Russian Government for the verification of instruments. The Committee recommend that a sum of £600 should be granted for the expenditure of the current year.

Kew Observatory,
14 August, 1863.

JOHN P. GASSIOT,
Chairman.

Report of the Parliamentary Committee, to the Meeting of the British Association, at Newcastle-on-Tyne, in August, 1863.

The Parliamentary Committee have the honour to report as follows:—

"The Earls of Rosse and De Grey, Lord Stanley, and Sir Joseph Paxton have vacated their seats; but your Committee recommend that Lords Rosse and Stanley be re-elected.

"Your Committee also recommend that two of the vacancies be supplied by the election of Lord Houghton and Mr. N. Kendall.

"A Committee of the House of Commons having reported in favour of the adoption of the Metrical System of Weights and Measures, and it being understood that a Bill to carry into effect such recommendation will be introduced in the ensuing Session of Parliament, your Committee venture to suggest that the expediency of such a measure might be discussed at the ensuing Meeting.

"No subject has been referred to your Committee since the last Meeting at Cambridge."

WROTTESLEY, *Chairman.*

24 August 1863.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE NEWCASTLE-UPON-TYNE MEETING IN AUGUST AND SEPTEMBER 1863.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the sum of £600 be placed at the disposal of the Council for maintaining the Establishment of the Kew Observatory.

That the Committee on Luminous Meteors and Aërolites, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. E. W. Brayley, and Mr. Alexander Herschel, be reappointed; and that the sum of £20 be placed at their disposal for the purpose.

That the Committee on the Connexion of Vertical Movements of the Atmosphere with Storms, consisting of Professor Hennessy, Admiral FitzRoy, and Mr. Glaisher, be reappointed; and that the sum of £30 be placed at their disposal for the purpose.

That Mr. G. J. Symons be requested to report on the Rain-fall of the British Isles during the years 1862 and 1863; and that the sum of £20 be placed at his disposal for the purpose of constructing and transmitting Rain-guages to districts where observations are not at present made. The Gauges to be sent within the British Isles, and the loan to be cancelled should the observations not be satisfactorily made.

That the Committee on Electrical Standards, consisting of Professor Williamson, Professor Wheatstone, Professor W. Thomson, Professor Miller, Dr. A. Matthiessen, Mr. Fleeming Jenkin, Dr. Esselbach, Sir C. Bright, Professor Maxwell, Mr. C. W. Siemens, and Mr. Balfour Stewart, be reappointed, with the addition of Dr. Joule and Mr. C. F. Varley; and that the sum of £100 be placed at their disposal for the purpose; and that the cooperation of the Royal Society be requested in the construction of Standard Electrical Instruments.

That Mr. Griffith and Dr. Akin be a Committee for the purpose of executing the experiments suggested by Dr. Akin in his paper on the Transmutation of Spectral Rays; and that the sum of £45 be placed at their disposal for the purpose.

That the Balloon Committee, consisting of Colonel Sykes, Professor Airy, Lord Wrottesley, Sir David Brewster, Sir J. Herschel, Dr. Lloyd, Admiral FitzRoy, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Dr. Tyndall, Mr. Fairbairn, and Dr. W. A. Miller, be reappointed; and that the sum of £200 be placed at their disposal for the following purposes:—1st. To ex-

amine the Electrical Condition of the Atmosphere at different heights. 2nd. To verify the law of decrease of temperature obtained by Mr. Glaisher, and to compare the constants obtained in different states of the Atmosphere.

That Dr. Matthiessen be requested to investigate the Chemical Constitution of Cast Iron; and that the sum of £20 be placed at his disposal for the purpose.

That Dr. Dupré be requested to continue his Researches on the Action of Reagents on Carbon under pressure; and that the sum of £10 be placed at his disposal for the purpose.

That Mr. Alphonse Gages be requested to continue his examinations of the Mechanical Structure of Rocks and Artificial Formation of Minerals; and that the sum of £10 be placed at his disposal for the purpose.

That Professor Huxley and Sir P. Egerton be a Committee for the purpose of enabling Mr. Molyneux to continue his Researches into the Fossil Contents of North Staffordshire; and that the sum of £20 be placed at their disposal for the purpose.

That Sir W. Armstrong, Professor Phillips, Professor Warington Smyth, and Professor Pole be a Committee for the purpose of inquiring into the probable duration of those seams of coal upon which the prosperity of the country depends; and that the sum of £100 be placed at their disposal for the purpose.

That Professor Huxley and the Rev. Mr. Macbride be a Committee for the purpose of conducting Experiments on the Artifical Fecundation of the Herring; and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Carpenter, Professor Huxley, and Professor T. Rupert Jones, assisted by Mr. Parker, be a Committee for the purpose of constructing a Series of Models showing the External and Internal Structure of the Foraminifera; and that the sum of £25 be placed at their disposal for the purpose.

That Sir W. Jardine, Mr. A. R. Wallace, Dr. J. E. Gray, Professor C. C. Babington, Dr. Francis, Dr. P. L. Sclater, Mr. C. Spence Bate, Mr. P. P. Carpenter, Dr. J. D. Hooker, Professor Balfour, Mr. H. T. Stainton, Mr. J. Gywn Jeffreys, Mr. A Newton, Professor T. H. Huxley, Professor Allman, and Mr. Bentham, with power to add to their number, be a Committee to report on the changes which they may consider it desirable to make, if any, in the Rules of Nomenclature drawn up at the instance of the British Association in 1843 by Mr. Strickland and others, with power to *reprint* these Rules, and to correspond with Foreign naturalists and others, on the best means of ensuring their general adoption; and that the sum of £15 be placed at their disposal for the purpose.

That Dr. B. W. Richardson, Dr. George Rolleston, and Dr. George Gibb be a Committee for the purpose of investigating the Physiological Action of Nitrite of Amyle; and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Allman be requested to complete his Report on the Hydroida, and that Dr. Allman and Dr. E. Perceval Wright be a Committee for that purpose; and that the sum of £10 be placed at their disposal for that purpose.

That Mr. J. Gywn Jeffreys, Mr. Joshua Alder, Mr. H. T. Mennell, Mr. J. S. Brady, and Mr. Albany Hancock be a Committee for the purpose of exploring the coasts of Durham and Northumberland by means of the Dredge; and that the sum of £25 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Rev. A. M. Norman, Professor Allman, Rev. Thomas Hincks, and Mr. J. Leckenby be a Committee for the purpose of

dredging the coasts of Shetland by means of the Dredge; and that the sum of £75 be placed at their disposal for the purpose.

That Mr. J. Gwyn Jeffreys, Mr. Robert McAndrew, Mr. G. C. Hyndman, Professor Allman, Dr. Collingwood, Dr. Edwards, Professor Greene, Rev. Thomas Hincks, Mr. R. D. Darbishire, Mr. C. Spence Bate, Rev. A. M. Norman, and Dr. E. Perceval Wright be reappointed as a General Dredging Committee; and that the sum of £10 be placed at their disposal for the purpose.

That Mr. John Crawfurd, Mr. John Lubbock, Professor Huxley, and Mr. Francis Galton as Secretary, be a Committee for the purpose of aiding the Researches of Mr. George Busk on Typical Crania; and that the sum of £50 be placed at their disposal for the purpose.

That Professor Rankine, Mr. James R. Napier, and Mr. Scott Russell be a Committee for the purpose of experimenting on the difference between the resistance of floating bodies moving along the surface of the water and similar bodies moving under water; and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Steamship Performance, consisting of the Duke of Sutherland, The Earl of Gifford, The Earl of Caithness, Lord Dufferin, Mr. W. Fairbairn, Mr. J. Scott Russell, Admiral Paris, The Hon. Captain Egerton, R.N., The Hon. L. A. Ellis, Mr. J. E. McConnell, Mr. W. Smith, Professor J. Macquorn Rankine, Mr. James Napier, Mr. Richard Roberts, Mr. Henry Wright to be Honorary Secretary, be reappointed, and requested to continue their labours and report in a more condensed form than heretofore the returns of Steamship Performance received by them; and that the sum of £60 be placed at their disposal for the purpose.

That the Committee for Tidal Observations in the Humber, consisting of Mr. J. Oldham, Mr. J. F. Bateman, Mr. J. Scott Russell, and Mr. Thomson, be reappointed; and that the grant of £50 made last year and not drawn be renewed.

That the Joint Committee on Gun-Cotton, consisting of Mr. W. Fairbairn, Mr. Joseph Whitworth, Mr. James Nasmyth, Mr. J. Scott Russell, Mr. John Anderson, Sir W. Armstrong, Dr. Gladstone, Professor W. A. Miller, and Dr. Frankland, be reappointed, with the addition of Mr. Abel; and that the sum of £50 be placed at their disposal for the purpose.

That in consideration of the long and valuable services of the late Mr. W. Askham, and the insufficient provision made for his family, the sum of £50 be presented to his widow.

Applications for Reports and Researches not involving Grants of Money.

That Mr. Fleeming Jenkin be requested to continue his Report on Thermo-Electrical Phenomena.

That the Committee on Fog Signals, consisting of Dr. Robinson, Professor Wheatstone, Dr. Gladstone, and Professor Hennessy, be reappointed and requested to continue their labours.

That Professor Foster be requested to continue his Report on Organic Chemistry.

That Dr. J. E. Gray, Dr. Sclater, Mr. A. Newton, and Mr. A. R. Wallace be a Committee for the purpose of investigating the subject of the Geographical Distribution of Domestic Animals.

That Mr. S. Gregson, M.P., Dr. Neilson Hancock, Mr. James Heywood, Mr. W. Tite, M.P., Mr. Thomas Wilson, and Mr. F. Purdy as Secretary (with power to add to their number), be a Committee for the purpose of considering and reporting on the subject of Agricultural Statistics.

That Mr. Francis Galton be requested to report on Systems of Weights and Measures, other than purely decimal, suitable for general adoption.

That Professor Rankine, Sir William Armstrong, Lord Wrottesley, Sir John Herschel, The Astronomer Royal, General Sabine, Dr. Lee, The Rev. Dr. Robinson, Mr. W. Tite, M.P., Colonel Sykes, M.P., Sir John Hay, Bart., M.P., the Right Hon. C. B. Adderley, M.P., Mr. W. Ewart, M.P., Mr. James Heywood, Professor Williamson, Professor Miller, and Mr. F. Purdy, as Secretary (with power to add to their number), be a Committee to prepare a Report on the best means of providing for a Uniformity of Weights and Measures with reference to the interests of Science.

That the Committee on Scientific Evidence in Courts of Law, consisting of the Rev. W. Vernon Harcourt, Right Hon. Joseph Napier, Mr. W. Tite, M.P., Professor Christison, Mr. J. Heywood, Mr. J. E. Bateman, Mr. T. Webster (with power to add to their number), be reappointed, and that Dr. Miller, Professor Williamson, and Sir B. C. Brodie, Bart. be added to the Committee.

Involving Applications to Governments.

That the President of the British Association be requested to transmit the thanks of the Association to the English and Austrian Governments for the facilities they have afforded for the investigation into the properties and applications of Gun-Cotton contained in the Report of the Committee.

That it appears from the Report presented at this Meeting by the Joint Committees of the Chemical and Mechanical Sections, and by the discussions which have followed its presentation, that the subject of Gun-cotton is possibly one of very great public interest and importance, and that whilst the General Committee have taken measures to continue on their own account the inquiries which have been prosecuted in the last year, they are sensible that the British Association does not possess means for its adequate examination; they are desirous therefore of drawing the attention of Her Majesty's Government to the importance of a full and searching inquiry, conducted by a Royal Commission, into the various practical applications connected with the public service for which this material may be suitable, and that with this view the Assistant-General Secretary be requested to cause the Report, with its accompanying documents, to be printed with as little delay as possible, and copies presented (accompanied by the Resolution) to the Right Honourable the Secretary of State for War by a deputation consisting of the President and Officers of the Association, accompanied by the Presidents of the Chemical and Mechanical Sections.

Communications to be printed entire among the Reports.

That the General and Assistant-General Secretaries ascertain, in reference to the papers which have been provisionally passed for printing in *extenso*, the probable extent of the printing involved, and the probable extra cost in tables, diagrams and plates, and the suitability of the paper in other respects, before ordering the printing of them; the Secretaries being authorized to obtain any assistance from the Presidents of Sections or other competent persons.

That an Account of the Newcastle-on-Tyne Time-gun, by Professor Piazzi Smyth, be printed entire among the Reports.

That the Report on the Metallurgy of the District, by Messrs. Bell, Richardson, Sopwith, and Spencer, be printed *in extenso* in the Proceedings of the Association.

That the Report on the Chemical Manufactures of the Northern District, by Messrs. J. C. Stevenson, R. C. Clapham, and T. Richardson, be printed *in extenso* in the Transactions of the Association.

That the Paper by Messrs. Daglish and Foster, on the Magnesian Limestone of the County of Durham, be printed in full in the Report.

That Mr. Palmer's Paper on Iron Ship-building on the Tyne and the neighbouring districts be printed in full in the Transactions.

That Dr. Allman's Report on Hydroida be published *in extenso*, with illustrations, in the Proceedings.

That an abstract by Dr. Edward Smith of the Report by Civil Medical Officers on the nature, growth, and mode of preparation of the various alimentary articles consumed as food by the industrial and labouring population in the several districts of Bengal, be printed entire among the Reports.

That Mr. C. W. Siemens's Paper on the Electrification of Gutta Percha be printed *in extenso*.

That Dr. Akin's Paper on the Transmutation of Spectral Rays be printed *in extenso*.

That Professor Airy's Paper on Steam-Boiler Explosions be printed in full in the Transactions.

That the Address of Sir Roderick Murchison, the President of Section E, be printed.

That the Address of Professor Williamson, President of Section B, be printed *in extenso*.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Newcastle Meeting in August and September 1863, *with the name of the Member who alone, or as the First of a Committee, is entitled to draw the Money.*

Kew Observatory.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0

Mathematics and Physics.

	£	s.	d.
Glaisher, Mr.—Meteors	20	0	0
Hennessy, Prof.—Vertical Atmospheric Movements	30	0	0
Symons, Mr.—Rainfall in 1862–63	20	0	0
Williamson, Prof.—Electrical Standards	100	0	0
Griffith, Mr.—Transmutation of Spectral Rays	45	0	0
Sykes, Col.—Balloon Ascents	200	0	0

Chemistry.

	£	s.	d.
Matthiessen, Dr.—Cast Iron	20	0	0
Dupré, M.—Carbon under pressure	10	0	0
Gages, Mr.—Mechanical Structure of Rocks	10	0	0

Geology.

Huxley, Prof.—Fossil Contents of the Staffordshire Coal Field	20	0	0
Armstrong, Sir W.—Quantity of Coal	100	0	0

Zoology and Botany.

Huxley, Prof.—Herrings	10	0	0
Carpenter, Dr.—Foraminifera	25	0	0
Jardine, Sir W.—Nomenclature	15	0	0
Richardson, Dr.—Nitrite of Amyle	10	0	0
Allman, Prof.—Hydroida	10	0	0
Jeffreys, Mr.—Dredging (coast of Durham and Northumberland)	25	0	0
Jeffreys, Mr.—Dredging (Shetland)	75	0	0
Jeffreys, Mr.—General Dredging Committee	10	0	0

Geography and Ethnology.

Crawfurd, Mr. J.—Crania	50	0	0

Mechanics.

Rankine, Prof.—Resistance of Moving Bodies	100	0	0
Sutherland, Duke of.—Steamships	60	0	0
Oldham, Mr.—Tidal Observations	50	0	0
Fairbairn, Mr. W.—Gun-Cotton	50	0	0
	1665	0	0
Askham, Mr.	50	0	0
Total	1715	0	0

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Cooperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants......	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas.....1842	100	0	0
Geographical Distributions of Marine Zoology............1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument, 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Cooperation	16	16	8
Meteorological Instruments at Edinburgh..........................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells...	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds...............1843	2	0	7
Vitality of Seeds...............1844	7	0	0
Marine Zoology of Cornwall......	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839...............	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials...............	60	0	0
Researches in Asphyxia............	6	16	2
Examination of Fossil Shells......	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall......	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall ...	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants...............	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants...............	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0

	£	s.	d.
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

1851.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.

	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.

	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860 ...... £50 0 0; 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-East Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.	£	s.	d.
Maintaining Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroids	10	0	0
	£1608	3	10

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money for scientific purposes have been entrusted, are required to present to each following meeting of the Association a Report of the progress which has been made; with a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of pecuniary aid for scientific purposes from the funds of the Association expire at the ensuing meeting, unless it shall appear by a Report that the Recommendations have been acted on, or a continuation of them be ordered by the General Committee.

In each Committee, the Member first named is the person entitled to call on the Treasurer, William Spottiswoode, Esq., 59 Grosvenor Place, London, S.W., for such portion of the sum granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named shall be deemed to include, as a part of the amount, the specified balance which may remain unpaid on the former grant for the same object.

General Meetings.

On Wednesday Evening, August 26, at 8 P.M., in the Town Hall, the Rev. R. Willis, M.A., F.R.S., resigned the office of President to Sir W. G. Armstrong, LL.D., F.R.S., who took the Chair, and delivered an Address, for which see page li.

On Thursday Evening, August 27, at 8 P.M., a Soirée took place in the Central Exchange News Room.

On Friday Evening, August 28, at 8.30 P.M., in the Town Hall, Professor Williamson delivered a Discourse on the Chemistry of the Galvanic Battery considered in relation to Dynamics.

On Monday Evening, August 31, at 8 P.M., a Soirée took place in the Central Exchange News Room.

On Tuesday Evening, September 1, at 8.30 P.M., Mr. Glaisher gave an account of the Balloon Ascents made for the British Association.

On Wednesday, September 2, at 3 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Bath*.

* The Meeting is appointed to take place on Wednesday, September 14, 1864.

ADDRESS

BY

SIR WILLIAM G. ARMSTRONG, C.B., LL.D., F.R.S., &c.

Gentlemen of the British Association,—I esteem it the greatest honour of my life that I am called upon to assume the office of your President. In that capacity, and as representing your body, I may be allowed to advert to the gratifying reception which the British Association met with on their former visit to this region of mining and manufacturing industry, and, as a member of the community which you have again honoured with a visit, I undertake to convey to you the assurance of a renewed and hearty welcome. A quarter of a century has elapsed since the Association assembled in this town, and in no former period of equal duration has so great a progress been made in physical knowledge. In mechanical science, and especially in those branches of it which are concerned in the application of steam power to effect interchange between distant communities, the progress made since 1838 has no parallel in history. The railway system was then in its infancy, and the great problem of transatlantic steam navigation had only received its complete solution in the preceding year. Since that time railways have extended to every continent, and steamships have covered the ocean. These reflections claim our attention on this occasion, because the locality in which we hold our present meeting is the birthplace of railways, and because the coal-mines of this district have contributed more largely than any others to supply the motive power by which steam communication by land and water has been established on so gigantic a scale.

The history of railways shows what grand results may have their origin in small beginnings. When coal was first conveyed in this neighbourhood from the pit to the shipping-place on the Tyne, the pack-horse, carrying a burden of 3 cwt., was the only mode of transport employed. As soon as roads suitable for wheeled carriages were formed, carts were introduced, and this first step in mechanical appliance to facilitate transport had the effect of increasing the load which the horse was enabled to convey from 3 cwt. to 17 cwt. The next improvement consisted in laying wooden bars or rails for the wheels of the carts to run upon, and this was followed by the substitution of the four-wheeled wagon for the two-wheeled cart. By this further application of mechanical principles the original horseload of 3 cwt. was augmented to 42 cwt. These were important results, and they were not obtained without the shipwreck of the fortunes of at least one adventurous man whose ideas were in advance of the times in which he lived. We read, in a record published in the year 1649, that "one Master Beaumont, a gentleman of great ingenuity and rare parts, adventured into the mines of Northumberland with his £30,000, and brought with him many rare engines not then known in that shire, and wagons with one horse to carry down coal from the pits to the river, but within a few years he consumed all his money and rode home upon his light horse." The next step in the progress of railways was the attachment of slips of iron to the wooden rails. Then came the iron tram-

way, consisting of cast-iron bars of an angular section: in this arrangement the upright flange of the bar acted as a guide to keep the wheel on the track. The next advance was an important one, and consisted in transferring the guiding flange from the rail to the wheel: this improvement enabled cast-iron edge rails to be used. Finally, in 1820, after the lapse of about 200 years from the first employment of wooden bars, wrought-iron rails, rolled in long lengths, and of suitable section, were made in this neighbourhood, and eventually superseded all other forms of railway. Thus, the railway system, like all large inventions, has risen to its present importance by a series of steps; and so gradual has been its progress, that Europe finds itself committed to a gauge fortuitously determined by the distance between the wheels of the carts for which wooden rails were originally laid down.

Last of all came the locomotive engine, that crowning achievement of mechanical science, which enables us to convey a load of 200 tons at a cost of fuel scarcely exceeding that of the corn and hay which the original pack-horse consumed in conveying its load of 3 cwt. an equal distance.

It was chiefly in this locality that the railway system was thus reared from earliest infancy to full maturity, and amongst the many names associated with its growth, that of George Stephenson stands preeminent.

In thus glancing at the history of railways, we may observe how promptly the inventive faculty of man supplies the device which the circumstances of the moment require. No sooner is a road formed fit for wheeled carriages to pass along, than the cart takes the place of the pack-saddle: no sooner is the wooden railway provided than the wagon is substituted for the cart: and no sooner is an iron railway formed, capable of carrying heavy loads, than the locomotive engine is found ready to commence its career. As in the vegetable kingdom fit conditions of soil and climate quickly cause the appearance of suitable plants, so in the intellectual world fitness of time and circumstance promptly calls forth appropriate devices. The seeds of invention exist, as it were, in the air, ready to germinate whenever suitable conditions arise, and no legislative interference is needed to ensure their growth in proper season.

The coal-fields of this district, so intimately connected with the railway system, both in its origin and maintenance, will doubtless receive much attention from the Association at their present meeting.

To persons who contend that all geological phenomena may be attributed to causes identical in nature and degree with those now in operation, the formation of coal must present peculiar difficulty. The rankness of vegetation which must have existed in the carboniferous era, and the uniformity of climate which appears to have prevailed almost from the Poles to the Equator, would seem to imply a higher temperature of the earth's crust, and an atmosphere more laden with humidity and carbonic acid than exist in our day. But whatever may have been the geological conditions affecting the origin of coal, we may regard the deposits of that mineral as vast magazines of power stored up at periods immeasurably distant for our use.

The principle of conservation of force and the relationship now established between heat and motion, enable us to trace back the effects which we now derive from coal to equivalent agencies exercised at the periods of its formation. The philosophical mind of George Stephenson, unaided by theoretical knowledge, rightly saw that coal was the embodiment of power originally derived from the sun. That small pencil of solar radiation which is arrested by our planet, and which constitutes less than the 2000-millionth part of the total energy sent forth from the sun, must be regarded as the power which

enabled the plants of the carboniferous period to wrest the carbon they required from the oxygen with which it was combined, and eventually to deposit it as the solid material of coal. In our day, the reunion of that carbon with oxygen restores the energy expended in the former process, and thus we are enabled to utilize the power originally derived from the luminous centre of our planetary system.

But the agency of the sun in originating coal does not stop at this point. In every period of geological history the waters of the ocean have been lifted by the action of the sun and precipitated in rain upon the earth. This has given rise to all those sedimentary actions by which mineral substances have been collected at particular localities, and there deposited in a stratified form with a protecting cover to preserve them for future use. The phase of the earth's existence suitable for the extensive formation of coal appears to have passed away for ever; but the quantity of that invaluable mineral which has been stored up throughout the globe for our benefit is sufficient (if used discreetly) to serve the purposes of the human race for many thousands of years. In fact, the entire quantity of coal may be considered as practically inexhaustible. Turning, however, to our own particular country, and contemplating the rate at which we are expending those seams of coal which yield the best quality of fuel, and can be worked at the least expense, we shall find much cause for anxiety. The greatness of England much depends upon the superiority of her coal in cheapness and quality over that of other nations; but we have already drawn from our choicest mines a far larger quantity of coal than has been raised in all other parts of the world put together, and the time is not remote when we shall have to encounter the disadvantages of increased cost of working and diminished value of produce.

Estimates have been made at various periods of the time which would be required to produce complete exhaustion of all the accessible coal in the British Islands. These estimates are extremely discordant; but the discrepancies arise, not from any important disagreement as to the available quantity of coal, but from the enormous difference in the rate of consumption at the various dates when the estimates were made, and also from the different views which have been entertained as to the probable increase of consumption in future years. The quantity of coal yearly worked from British mines has been almost trebled during the last twenty years, and has probably increased tenfold since the commencement of the present century; but as this increase has taken place pending the introduction of steam navigation and railway transit, and under exceptional conditions of manufacturing development, it would be too much to assume that it will continue to advance with equal rapidity. The statistics collected by Mr. Hunt, of the Mining Record Office, show that at the end of 1861 the quantity of coal raised in the United Kingdom had reached the enormous total of 86 millions of tons, and that the average annual increase of the eight preceding years amounted to $2\frac{3}{4}$ millions of tons. Let us inquire, then, what will be the duration of our coal-fields if this more moderate rate of increase be maintained.

By combining the known thickness of the various workable seams of coal, and computing the area of the surface under which they lie, it is easy to arrive at an estimate of the total quantity comprised in our coal-bearing strata. Assuming 4000 feet as the greatest depth at which it will ever be possible to carry on mining operations, and rejecting all seams of less than 2 feet in thickness, the entire quantity of available coal existing in these Islands has been calculated to amount to about 80,000 millions of tons,

which, at the present rate of consumption, would be exhausted in 930 years, but, with a continued yearly increase of $2\frac{3}{4}$ millions of tons, would only last 212 years. It is clear that long before complete exhaustion takes place, England will have ceased to be a coal-producing country on an extensive scale. Other nations, and especially the United States of America, which possess coal-fields 37 times more extensive than ours, will then be working more accessible beds at a smaller cost, and will be able to displace the English coal from every market. The question is, not how long our coal will endure before absolute exhaustion is effected, but how long will those particular coal-seams last which yield coal of a quality and at a price to enable this country to maintain her present supremacy in manufacturing industry. So far as this particular district is concerned, it is generally admitted that 200 years will be sufficient to exhaust the principal seams even at the present rate of working. If the production should continue to increase as it is now doing, the duration of those seams will not reach half that period. How the case may stand in other coal-mining districts I have not the means of ascertaining; but as the best and most accessible coal will always be worked in preference to any other, I fear the same rapid exhaustion of our most valuable seams is everywhere taking place. Were we reaping the full advantage of all the coal we burnt, no objection could be made to the largeness of the quantity, but we are using it wastefully and extravagantly in all its applications. It is probable that fully one-fourth of the entire quantity of coal raised from our mines is used in the production of heat for motive power; but, much as we are in the habit of admiring the powers of the steam-engine, our present knowledge of the mechanical energy of heat shows that we realize in that engine only a small part of the thermic effect of the fuel. That a pound of coal should, in our best engines, produce an effect equal to raising a weight of a million pounds a foot high, is a result which bears the character of the marvellous, and seems to defy all further improvement. Yet the investigations of recent years have demonstrated the fact that the mechanical energy resident in a pound of coal, and liberated by its combustion, is capable of raising to the same height 10 times that weight. But although the power of our most economical steam-engines has reached, or perhaps somewhat exceeded, the limit of a million pounds raised a foot high per lb. of coal, yet, if we take the average effect obtained from steam-engines of the various constructions now in use, we shall not be justified in assuming it at more than one-third of that amount. It follows therefore that the average quantity of coal which we expend in realizing a given effect by means of the steam-engine is about 30 times greater than would be requisite with an absolutely perfect heat-engine.

The causes which render the application of heat so uneconomic in the steam-engine have been brought to light by the discovery of the dynamical theory of heat; and it now remains for mechanicians, guided by the light they have thus received, to devise improved practical methods of converting the heat of combustion into available power.

Engines in which the motive power is excited by the communication of heat to fluids already existing in the aëriform condition, as in those of Stirling, Ericson, and Siemens, promise to afford results greatly superior to those obtained from the steam-engine. They are all based upon the principle of employing fuel to generate sensible heat, to the exclusion of latent heat, which is only another name for heat which has taken the form of unprofitable motion amongst the particles of the fluid to which it is applied. They also

embrace what is called the regenerative principle—a term which has, with reason, been objected to, as implying a restoration of expended heat. The so called "regenerator" is a contrivance for arresting unutilized heat rejected by the engine, and causing it to operate in aid and consequent reduction of fuel.

It is a common observation that before coal is exhausted some other motive agent will be discovered to take its place, and electricity is generally cited as the coming power. Electricity, like heat, may be converted into motion, and both theory and practice have demonstrated that its mechanical application does not involve so much waste of power as takes place in a steam-engine; but whether we use heat or electricity as a motive power, we must equally depend upon chemical affinity as the source of supply. The act of uniting to form a chemical product liberates an energy which assumes the form of heat or electricity, from either of which states it is convertible into mechanical effect. In contemplating, therefore, the application of electricity as a motive power, we must bear in mind that we shall still require to effect chemical combinations, and in so doing to consume materials. But where are we to find materials so economical for this purpose as the coal we derive from the earth and the oxygen we obtain from the air? The latter costs absolutely nothing; and every pound of coal, which in the act of combustion enters into chemical combination, renders more than two and a half pounds of oxygen available for power. We cannot look to water as a practicable source of oxygen, for there it exists in the combined state, requiring expenditure of chemical energy for its separation from hydrogen. It is in the atmosphere alone that it can be found in that free state in which we require it, and there does not appear to me to be the remotest chance, in an economic point of view, of being able to dispense with the oxygen of the air as a source either of thermodynamic or electrodynamic effect. But to use this oxygen we must consume some oxidizable substance, and coal is the cheapest we can procure.

There is another source of motive power to which I am induced to refer, as exhibiting a further instance in which solar influence affords the means of obtaining mechanical effects from inanimate agents. I allude to the power of water descending from heights to which it has been lifted by the evaporative action of the sun. To illustrate the great advantage of collecting water for power in elevated situations I may refer to the waterworks of Greenock, where the collecting-reservoirs are situated at an elevation of 512 feet above the river Clyde. The daily yield of these reservoirs is said to be nearly 100,000 tons of water, which is derived from the rainfall on an area of 5000 acres. The power obtainable from this quantity and head of water is equal to that of a steam-engine of about 2000 horse-power, and the whole effect might be realized on the margin of the river by bringing down the water in a pipe of sufficient capacity, and causing it to act as a column on suitable machinery at the foot of the descent. But the hydraulic capabilities of the Greenock reservoirs sink into insignificance when compared with those of other localities where the naturally collected waters of large areas of surface descend from great elevations in rapid rivers or vertical falls. Alpine regions abound in falls which, with the aid of artificial works to impound the surplus water and equalize the supply, would yield thousands of horse-power; and there is at least one great river in the world which in a single plunge developes sufficient power to carry on all the manufacturing operations of mankind if concentrated in its neighbourhood. Industrial populations have scarcely yet extended to those regions which afford this profusion of motive power, but we may anticipate the time

when these natural falls will be brought into useful operation. In that day the heat of the sun, by raising the water to heights from which to flow in these great rapids and cascades, will become the means of economizing the precious stores of motive power, which the solar energy differently directed has accumulated at a remote period of geological history, and which when once expended may probably never be replaced.

I have hitherto spoken of coal only as a source of mechanical power, but it is also extensively used for the kindred purpose of relaxing those cohesive forces which resist our efforts to give new forms and conditions to solid substances. In these applications, which are generally of a metallurgical nature, the same wasteful expenditure of fuel is everywhere observable. In an ordinary furnace employed to fuse or soften any solid substance, it is the excess of the heat of combustion over that of the body heated which alone is rendered available for the purpose intended. The rest of the heat, which in many instances constitutes by far the greater proportion of the whole, is allowed to escape uselessly into the chimney. The combustion also in common furnaces is so imperfect, that clouds of powdered carbon, in the form of smoke, envelope our manufacturing towns, and gases, which ought to be completely oxygenized in the fire, pass into the air with two-thirds of their heating power undeveloped.

Some remedy for this state of things, we may hope, is at hand, in the gas regenerative furnaces recently introduced by Mr. Siemens. In these furnaces the rejected heat is arrested by a so-called "regenerator," as in Stirling's air-engine, and is communicated to the new fuel before it enters the furnace. The fuel, however, is not solid coal, but gas previously evolved from coal. A stream of this gas raised to a high temperature by the rejected heat of combustion is admitted into the furnace, and there meets a stream of atmospheric air also raised to a high temperature by the same agency. In the combination which then ensues, the heat evolved by the combustion is superadded to the heat previously acquired by the gases. Thus, in addition to the advantage of economy, a greater intensity of heat is attained than by the combustion of unheated fuel. In fact, as the heat evolved in the furnace, or so much of it as is not communicated to the bodies exposed to its action, continually returns to augment the effect of the new fuel, there appears to be no limit to the temperature attainable, except the powers of resistance in the materials of which the furnace is composed.

With regard to smoke, which is at once a waste and a nuisance, having myself taken part with Dr. Richardson and Mr. Longridge in a series of experiments made in this neighbourhood in the years 1857–58 for the purpose of testing the practicability of preventing smoke in the combustion of bituminous coal in steam-engine boilers, I can state with perfect confidence that, so far as the raising of steam is concerned, the production of smoke is unnecessary and inexcusable. The experiments to which I refer proved beyond a doubt, that by an easy method of firing, combined with a due admission of air and a proper arrangement of firegrate, not involving any complexity, the emission of smoke might be perfectly avoided, and that the prevention of the smoke increased the economic value of the fuel and the evaporative power of the boiler. As a rule, there is more smoke evolved from the fires of steam-engines than from any others, and it is in these fires that it may be most easily prevented. But in the furnaces used for most manufacturing operations the prevention of smoke is much more difficult, and will probably not be effected until a radical change is made in the system of applying fuel for such operations.

Not less wasteful and extravagant is our mode of employing coal for domestic purposes. It is computed that the consumption of coal in dwelling-houses amounts in this country to a ton per head per annum of the entire population; so that upwards of twenty-nine millions of tons are annually expended in Great Britain alone for domestic use. If any one will consider that one pound of coal applied to a well-constructed steam-engine boiler evaporates 10 lbs. or one gallon of water, and if he will compare this effect with the insignificant quantity of water which can be boiled off in steam by a pound of coal consumed in an ordinary kitchen fire, he will be able to appreciate the enormous waste which takes place by the common method of burning coal for culinary purposes. The simplest arrangements to confine the heat and concentrate it upon the operation to be performed would suffice to obviate this reprehensible waste. So also in warming houses we consume in our open fires about five times as much coal as will produce the same heating effect when burnt in a close and properly constructed stove. Without sacrificing the luxury of a visible fire, it would be easy, by attending to the principles of radiation and convection, to render available the greater part of the heat which is now so improvidently discharged into the chimney. These are homely considerations—too much so, perhaps, for an assembly like this; but I trust that an abuse involving a useless expenditure exceeding in amount our income-tax, and capable of being rectified by attention to scientific principles, may not be deemed unworthy of the notice of some of those whom I have the honour of addressing.

The introduction of the Davy lamp was a great event in the history of coal-mining, not as effecting any great diminution of those disastrous accidents which still devastate every colliery district, but as a means of enabling mines to be worked which, from their greater explosive tendencies, would otherwise have been deemed inaccessible. Thus, while the Davy lamp has been of great benefit both to the public and the proprietors of coal, it has been the means of leading the miners into more perilous workings, and the frequency of accident by explosion has in consequence not been diminished to the extent which was originally expected. The Davy lamp is a beautiful application of a scientific principle to effect a practical purpose, and with fair treatment its efficiency is indisputable; but where Davy lamps are entrusted to hundreds of men, and amongst them to many careless and reckless persons, it is impossible to guard entirely against gross negligence and its disastrous consequences. In coal-mines where the most perfect system of ventilation prevails, and where proper regulations are, as far as practicable, enforced in regard to the use of Davy lamps, deplorable accidents do occasionally occur, and it is impossible at present to point out what additional precautions would secure immunity from such calamities. The only gleam of amelioration is in the fact that the loss of life in relation to the quantity of coal worked is on the decrease, from which we may infer that it is also on the decrease taken as a percentage on the number of miners employed.

The increase of the earth's temperature as we descend below the surface is a subject which has been discussed at previous Meetings of the British Association. It possesses great scientific interest as affecting the computed thickness of the crust which covers the molten mass assumed to constitute the interior portions of the earth, and it is also of great practical importance as determining the depth at which it would be possible to pursue the working of coal and other minerals. The deepest coal-mine in this district is the Monkwearmouth Colliery, which reaches a depth of 1800 feet below the surface of the ground, and nearly as much below the level of the sea. The

observed temperature of the strata at this depth agrees pretty closely with what has been ascertained in other localities, and shows that the increase takes place at the rate of 1° Fahr. to about 60 feet of depth. Assuming the temperature of subterranean fusion to be 3000°, and that the increase of heat at greater depths continues uniform (which, however, is by no means certain), the thickness of the film which separates us from the fiery ocean beneath will be about thirty-four miles—a thickness which may be fairly represented by the skin of a peach taken in relation to the body of the fruit which it covers. The depth of 4000 feet, which has been assumed as the limit at which coal could be worked, would probably be attended by an increase of heat exceeding the powers of human endurance. In the Monkwearmouth colliery, which is less than half that depth, the temperature of the air in the workings is about 84° Fahr., which is considered to be nearly as high as is consistent with the great bodily exertion necessary in the operation of mining. The computations therefore of the duration of coal would probably require a considerable reduction in consequence of too great a depth being assumed as practicable.

At the last Meeting of the British Association in this town, the importance of establishing an office for mining records was brought under the notice of the Council by Mr. Sopwith, and measures were taken which resulted in the formation of the present Mining Records Office. The British Association may congratulate itself upon having thus been instrumental in establishing an office in which plans of abandoned mines are preserved for the information of those who, at a future period, may be disposed to incur the expense of bringing those mines again into operation. But more than this is required. Many of the inferior seams of coal can be profitably worked only in conjunction with those of superior quality, and they will be entirely lost if neglected until the choicer beds be exhausted. Although coal is private property, its duration is a national question, and Government interference would be justified to enforce such modes of working as the national interests demand. But to enable Government to exercise any supervision and control, a complete mining survey of all our coal-fields should be made, and full plans, sections, and reports lodged at the Mining Records Office for the information of the legislature and of the public in general.

Before dismissing the subject of coal, it may be proper to notice the recent discovery by Berthelot of a new form of carburetted hydrogen possessing twice the illuminating power of ordinary coal-gas. Berthelot succeeded in procuring this gas by passing hydrogen between the carbon electrodes of a powerful battery. Dr. Odling has since shown that the same gas may be produced by mixing carbonic oxide with an equal volume of light carburetted hydrogen and exposing the mixture in a porcelain tube to an intense heat. Still more recently, Mr. Siemens has detected the same gas in the highly heated regenerators of his furnaces, and there is now every reason to believe that the new gas will become practically available for illuminating-purposes. Thus it is that discoveries which in the first instance interest the philosopher only almost invariably initiate a rapid series of steps leading to results of great practical importance to mankind.

In the course of the preceding observations I have had occasion to speak of the sun as the great source of motive power on our earth, and I must not omit to refer to recent discoveries connected with that most glorious body. Of all the results which science has produced within the last few years, none has been more unexpected than that by which we are enabled to test the materials of which the sun is made, and prove their identity, in part at least, with those

of our planet. The spectrum experiments of Bunsen and Kirchhoff have not only shown all this, but they have also corroborated previous conjectures as to the luminous envelope of the sun. I have still to advert to Mr. Nasmyth's remarkable discovery, that the bright surface of the sun is composed of an aggregation of apparently solid forms, shaped like willow-leaves or some well-known forms of Diatomaceæ, and interlacing one another in every direction. The forms are so regular in size and shape, as to have led to a suggestion from one of our profoundest philosophers of their being organisms, possibly even partaking of the nature of life, but at all events closely connected with the heating and vivifying influences of the sun. These mysterious objects, which, since Mr. Nasmyth discovered them, have been seen by other observers as well, are computed to be each not less than 1000 miles in length and about 100 miles in breadth. The enormous chasms in the sun's photosphere, to which we apply the diminutive term "spots," exhibit the extremities of these leaf-like bodies pointing inwards, and fringing the sides of the cavern far down into the abyss. Sometimes they form a sort of rope or bridge across the chasm, and appear to adhere to one another by lateral attraction. I can imagine nothing more deserving of the scrutiny of observers than these extraordinary forms. The sympathy also which appears to exist between forces operating in the sun and magnetic forces belonging to the earth merits a continuance of that close attention which it has already received from the British Association, and of labours such as General Sabine has with so much ability and effect devoted to the elucidation of the subject. I may here notice that most remarkable phenomenon which was seen by independent observers at two different places on the 1st of September 1859. A sudden outburst of light, far exceeding the brightness of the sun's surface, was seen to take place, and sweep like a drifting cloud over a portion of the solar face. This was attended with magnetic disturbances of unusual intensity and with exhibitions of aurora of extraordinary brilliancy. The identical instant at which the effusion of light was observed was recorded by an abrupt and strongly marked deflection in the self-registering instruments at Kew. The phenomenon as seen was probably only part of what actually took place, for the magnetic storm in the midst of which it occurred commenced before and continued after the event. If conjecture be allowable in such a case, we may suppose that this remarkable event had some connexion with the means by which the sun's heat is renovated. It is a reasonable supposition that the sun was at that time in the act of receiving a more than usual accession of new energy; and the theory which assigns the maintenance of its power to cosmical matter plunging into it with that prodigious velocity which gravitation would impress upon it as it approached to actual contact with the solar orb, would afford an explanation of this sudden exhibition of intensified light in harmony with the knowledge we have now attained that arrested motion is represented by equivalent heat. Telescopic observations will probably add new facts to guide our judgment on this subject, and, taken in connexion with observations on terrestrial magnetism, may enlarge and correct our views respecting the nature of heat, light, and electricity. Much as we have yet to learn respecting these agencies, we know sufficient to infer that they cannot be transmitted from the sun to the earth except by communication from particle to particle of intervening matter. Not that I speak of particles in the sense of the atomist. Whatever our views may be of the nature of particles, we must conceive them as centres invested with surrounding forces. We have no evidence, either from our senses or otherwise, of these centres being occupied by solid cores of indivisible incompressible matter

essentially distinct from force. Dr. Young has shown that even in so dense a body as water, these nuclei, if they exist at all, must be so small in relation to the intervening spaces, that a hundred men distributed at equal distances over the whole surface of England would represent their relative magnitude and distance. What then must be these relative dimensions in highly rarefied matter? But why encumber our conceptions of material forces by this unnecessary imagining of a central molecule? If we retain the forces and reject the molecule, we shall still have every property we can recognize in matter by the use of our senses or by the aid of our reason. Viewed in this light, matter is not merely a thing subject to force, but is itself composed and constituted of force.

The dynamical theory of heat is probably the most important discovery of the present century. We now know that each Fahrenheit degree of temperature in a pound of water is equivalent to a weight of 772 lbs. lifted 1 foot high, and that these amounts of heat and power are reciprocally convertible into one another. This theory of heat, with its numerical computation, is chiefly due to the labours of Mayer and Joule, though many other names, including those of Thomson and Rankine, are deservedly associated with its development. I speak of this discovery as one of the present age because it has been established in our time; but if we search back for earlier conceptions of the identity of heat and motion, we shall find (as we always do in such cases) that similar ideas have been held before, though in a clouded and undemonstrated form. In the writings of Lord Bacon we find it stated that heat is to be regarded as motion and nothing else. In dilating upon this subject, that extraordinary man shows that he had grasped the true theory of heat to the utmost extent that was compatible with the state of knowledge existing in his time. Even Aristotle seems to have entertained the idea that motion was to be considered as the foundation not only of heat, but of all manifestations of matter; and, for aught we know, still earlier thinkers may have held similar views.

The science of gunnery, to which I shall make but slight allusion on this occasion, is intimately connected with the dynamical theory of heat. When gunpowder is exploded in a cannon, the immediate effect of the affinities by which the materials of the powder are caused to enter into new combinations, is to liberate a force which first appears as heat, and then takes the form of mechanical power communicated in part to the shot and in part to the products of explosion which are also propelled from the gun. The mechanical force of the shot is reconverted into heat when the motion is arrested by striking an object, and this heat is divided between the shot and the object struck, in the proportion of the work done or damage inflicted upon each. These considerations recently led me, in conjunction with my friend Captain Noble, to determine experimentally, by the heat elicited in the shot, the loss of effect due to its crushing when fired against iron plates. Joule's law, and the known velocity of the shot, enabled us to compute the number of dynamical units of heat representing the whole mechanical power in the projectile, and by ascertaining the number of units developed in it by impact, we arrived at the power which took effect upon the shot instead of the plate. These experiments showed an enormous absorption of power to be caused by the yielding nature of the materials of which projectiles are usually formed; but further experiments are required to complete the inquiry.

Whilst speaking of the subject of gunnery, I must pay a passing tribute of praise to that beautiful instrument invented and perfected by Major Navez of the Belgian Artillery, for determining, by means of electro-magnetism, the

velocity of projectiles. This instrument has been of great value in recent investigations, and there are questions affecting projectiles which we can only hope to solve by its assistance. Experiments are still required to clear up several apparently anomalous effects in gunnery, and to determine the conditions most conducive to efficiency both as regards attack and defence. It is gratifying to see our Government acting in accordance with the enlightened principles of the age by carrying on scientific experiments to arrive at knowledge, which, in the arts of war as well as in those of peace, is proverbially recognized as the true source of human power.

Professor Tyndall's recent discoveries respecting the absorption and radiation of heat by vapours and permanent gases constitute important additions to our knowledge. The extreme delicacy of his experiments and the remarkable distinctness of their results render them beautiful examples of physical research. They are of great value as affording further illustrations of the vibratory actions in matter which constitute heat; but it is in connexion with the science of meteorology that they chiefly command our attention. From these experiments we learn that the minute quantity of water suspended as invisible vapour in the atmosphere acts as a warm clothing to the earth. The efficacy of this vapour in arresting heat is, in comparison with that of air, perfectly astounding. Although the atmosphere contains on an average but one particle of aqueous vapour to 200 of air, yet that single particle absorbs 80 times as much heat as the collective 200 particles of air. Remove, says Professor Tyndall, for a single summer night, the aqueous vapour from the air which overspreads this country, and you would assuredly destroy every plant incapable of bearing extreme cold. The warmth of our fields and gardens would pour itself unrequited into space, and the sun would rise upon an island held fast in the grip of frost. Many meteorological phenomena receive a feasible explanation from these investigations, which are probably destined to throw further light upon the functions of our atmosphere.

Few sciences have more practical value than meteorology, and there are few of which we as yet know so little. Nothing would contribute more to the saving of life and property, and to augmenting the general wealth of the world, than the ability to foresee with certainty impending changes of the weather. At present our means of doing so are exceedingly imperfect, but, such as they are, they have been employed with considerable effect by Admiral FitzRoy in warning mariners of the probable approach of storms. We may hope that so good an object will be effected with more unvarying success when we attain a better knowledge of the causes by which wind and rain, heat and cold are determined. The balloon explorations conducted with so much intrepidity by Mr. Glaisher, under the auspices of the British Association, may perhaps in some degree assist in enlightening us upon these important subjects. We have learnt from Mr. Glaisher's observations that the decrease of temperature with elevation does not follow the law previously assumed of 1° in 300 feet, and that in fact it follows no definite law at all. Mr. Glaisher appears also to have ascertained the interesting fact that rain is only precipitated when cloud exists in a double layer. Raindrops, he has found, diminish in size with elevation, merging into wet mist and ultimately into dry fog. Mr. Glaisher met with snow for a mile in thickness below rain, which is at variance with our preconceived ideas. He has also rendered good service by testing the efficiency of various instruments at heights which cannot be visited without personal danger.

The facility now given to the transmission of intelligence and the interchange of thought is one of the most remarkable features of the present

age. Cheap and rapid postage to all parts of the world—paper and printing reduced to the lowest possible cost—electric telegraphs between nation and nation, town and town, and now even (thanks to the beautiful inventions of Professor Wheatstone) between house and house—all contribute to aid that commerce of ideas by which wealth and knowledge are augmented. But while so much facility is given to mental communication by new measures and new inventions, the fundamental art of expressing thought by written symbols remains as imperfect now as it has been for centuries past. It seems strange that while we actually possess a system of shorthand by which words can be recorded as rapidly as they can be spoken, we should persist in writing a slow and laborious longhand. It is intelligible that grown-up persons who have acquired the present conventional art of writing should be reluctant to incur the labour of mastering a better system; but there can be no reason why the rising generation should not be instructed in a method of writing more in accordance with the activity of mind which now prevails. Even without going so far as to adopt for ordinary use a complete system of stenography, which it is not easy to acquire, we might greatly abridge the time and labour of writing by the recognition of a few simple signs to express the syllables which are of most frequent occurrence in our language. Our words are in a great measure made up of such syllables as *com*, *con*, *tion*, *ing*, *able*, *ain*, *ent*, *est*, *ance*, &c. These we are now obliged to write out over and over again, as if time and labour expended in what may be termed visual speech were of no importance. Neither has our written character the advantage of distinctness to recommend it: it is only necessary to write such a word as "minimum" or "ammunition" to become aware of the want of sufficient difference between the letters we employ. I refrain from enlarging on this subject, because I conceive that it belongs to social more than to physical science, although the boundary which separates the two is sufficiently indistinct to permit of my alluding to it in the hope of procuring for it the attention which its importance deserves.

Another subject of a social character which demands our consideration is the much-debated question of weights and measures. Whatever difference of opinion there may be as to the comparative merits of decimal and duodecimal division, there can, at all events, be none as to the importance of assimilating the systems of measurement in different countries. Science suffers by the want of uniformity, because valuable observations made in one country are in a great measure lost to another from the labour required to convert a series of quantities into new denominations. International commerce is also impeded by the same cause, which is productive of constant inconvenience and frequent mistake. It is much to be regretted that two standards of measure so nearly alike as the English yard and the French metre should not be made absolutely identical. The metric system has already been adopted by other nations besides France, and is the only one which has any chance of becoming universal. We in England, therefore, have no alternative but to conform with France, if we desire general uniformity. The change might easily be introduced in scientific literature, and in that case it would probably extend itself by degrees amongst the commercial classes without much legislative pressure. Besides the advantage which would thus be gained in regard to uniformity, I am convinced that the adoption of the decimal division of the French scale would be attended with great convenience, both in science and commerce. I can speak from personal experience of the superiority of decimal measurement in all cases where accuracy is required in mechanical construction. In the Elswick Works, as well as in

some other large establishments of the same description, the inch is adopted as the unit, and all fractional parts are expressed in decimals. No difficulty has been experienced in habituating the workmen to the use of this method, and it has greatly contributed to precision of workmanship. The inch, however, is too small a unit, and it would be advantageous to substitute the metre if general concurrence could be obtained. As to our thermometric scale, it was originally founded in error; it is also most inconvenient in division, and ought at once to be abandoned in favour of the Centigrade scale. The recognition of the metric system and of the Centigrade scale by the numerous men of science composing the British Association, would be a most important step towards effecting that universal adoption of the French standards in this country which sooner or later will inevitably take place; and the Association in its collective capacity might take the lead in this good work, by excluding in future all other standards from their published proceedings.

The recent discovery of the source of the Nile by Captains Speke and Grant has solved a problem in geography which has been a subject of speculation from the earliest ages. It is an honour to England that this interesting discovery has been made by two of her sons, and the British Association, which is accustomed to value every addition to knowledge for its own sake, whether or not it be attended with any immediate utility, will at once appreciate the importance of the discovery and the courage and devotion by which it has been accomplished. The Royal Geographical Society, under the able presidency of Sir Roderick Murchison, was chiefly instrumental in procuring the organization of the expedition which has resulted in this great achievement, and the success of the Society's labours in connexion with this and other cases of African exploration shows how much good may be effected by associations for the promotion of scientific objects.

The science of organic life has of late years been making great and rapid strides, and it is gratifying to observe that researches both in zoology and botany are characterized in the present day by great accuracy and elaboration. Investigations patiently conducted upon true inductive principles cannot fail eventually to elicit the hidden laws which govern the animated world. Neither is there any lack of bold speculation contemporaneously with this painstaking spirit of inquiry. The remarkable work of Mr. Darwin promulgating the doctrine of natural selection has produced a profound sensation. The novelty of this ingenious theory, the eminence of its author, and his masterly treatment of the subject have perhaps combined to excite more enthusiasm in its favour than is consistent with that dispassionate spirit which it is so necessary to preserve in the pursuit of truth. Mr. Darwin's views have not passed unchallenged, and the arguments both for and against have been urged with great vigour by the supporters and opponents of the theory. Where good reasons can be shown on both sides of a question, the truth is generally to be found between the two extremes. In the present instance we may without difficulty suppose it to have been part of the great scheme of creation that natural selection should be permitted to determine variations amounting even to specific differences where those differences were matters of degree; but when natural selection is adduced as a cause adequate to explain the production of a new organ not provided for in original creation, the hypothesis must appear, to common apprehensions, to be pushed beyond the limits of reasonable conjecture. The Darwinian theory, when fully enunciated, founds the pedigree of living nature upon the most elementary form of vitalized matter. One step further would carry us back, without greater violence to probability, to inorganic rudiments, and then we should be called upon to recognize in ourselves,

and in the exquisite elaborations of the animal and vegetable kingdoms, the ultimate results of mere material forces left free to follow their own unguided tendencies. Surely our minds would in that case be more oppressed with a sense of the miraculous than they now are in attributing the wondrous things around us to the creative hand of a Great presiding Intelligence.

The evidences bearing upon the antiquity of man have been recently produced in a collected and most logically-treated form by Sir Charles Lyell. It seems no longer possible to doubt that the human race has existed on the earth in a barbarian state for a period far exceeding the limit of historical record; but notwithstanding this great antiquity, the proofs still remain unaltered that man is the latest as well as the noblest work of God.

I will not run the risk of wearying this assembly by extending my remarks to other branches of science. In conclusion I will express a hope that when the time again comes round to receive the British Association in this town, its members will find the interval to have been as fruitful as the corresponding period on which we now look back. The tendency of progress is to quicken progress, because every acquisition in science is so much vantage ground for fresh attainment. We may expect, therefore, to increase our speed as we struggle forward; but however high we climb in the pursuit of knowledge we shall still see heights above us, and the more we extend our view, the more conscious we shall be of the immensity which lies beyond.

REPORTS

ON

THE STATE OF SCIENCE.

Report on the Application of Gun-cotton to Warlike purposes. By a Committee, consisting of J. H. Gladstone, *Ph.D., F.R.S.,* Prof. W. A. Miller, *M.D., F.R.S., and* Prof. E. Frankland, *Ph.D., F.R.S., from Section B.; and* W. Fairbairn, *LL.D., F.R.S.,* Joseph Whitworth, *F.R.S.,* James Nasmyth, *C.E., F.R.A.S.,* J. Scott Russell, *C.E., F.R.S.,* John Anderson, *C.E., and* Sir W. G. Armstrong, *C.B., LL.D., F.R.S., from Section G.*

Since the invention of gun-cotton by Professor Schönbein of Basle, the thoughts of many have been directed to its application to warlike purposes. Many trials and experiments have been made, especially by the French Government; but such serious difficulties and objections presented themselves, that the idea seemed to be abandoned in every country but one. That country was Austria. From time to time accounts reached England of its partial adoption in the Austrian service—though no explanation was afforded of the mode in which the difficulties had been overcome, or the extent to which these attempts had been successful.

This was the state of the case when the present Committee was appointed.

During the year your Committee have been put in possession of the fullest information on the subject, mainly from two sources, F. A. Abel, Esq., F.R.S., the Chemist to the War Department, and Baron William von Lenk, Major-General of the Austrian Artillery, who is the inventor of the system by which gun-cotton is made practically available for warlike purposes.

Mr. Abel, by permission of the Secretary of State for War, has communicated the information given by the Austrian Government to the Government of this country, and the results which he has himself arrived at during the course of an elaborate series of experiments.

General von Lenk, on the invitation of your Committee, and by permission of the Emperor of Austria, paid a visit to this country, with the object of answering any inquiries the Committee might make, and explaining his system thoroughly; and for this purpose he brought over drawings and samples from the Imperial factory.

In addition to these principal sources of information, your Committee would mention the services rendered by two of their own number. Prof. Frankland was able to corroborate by his own experiments most of the statements made in the earlier communications of Mr. Abel. Mr. Whitworth has made experiments on the application of gun-cotton in mines, and has sent over to Austria rifles and ammunition, to be experimented with by Baron von Lenk, with a view of obtaining results, which he has promised to communicate to the Committee.

The following documents form part of this Report, and contain the information received.

I. Report by Mr. Abel, received February 1863, on the system of manufacture of gun-cotton, as carried on in the Imperial Austrian Establishment.

II. Report by Mr. Abel, dated February 20th, 1863, on the composition, and some properties, of specimens of gun-cotton prepared at the Austrian Government Works.

III. Memorandum by Mr. Abel, with reference to experiments in progress bearing upon the manufacture of gun-cotton. Received August 27th, 1863.

IV. General von Lenk's replies to the questions put to him at the Meetings of June 22 and July 14.

V. Extracts from a report on Baron Lenk's gun-cotton by Profs. Redtenbacher, Schrötter, and Schneider. Dated June 1863.

On the data afforded by these documents, and other information communicated personally by Baron Lenk, your Committee have founded their present Report. It must therefore be regarded in the light of a preliminary inquiry. Should the Committee be reappointed, they will be happy to undertake some experiments with the view of clearing up those points which are still more or less obscure.

These communications are broken into paragraphs, which are numbered for convenience of reference; those of Mr. Abel are indicated by the letter A, those of Baron Lenk are distinguished by the letter L, whilst the extracts from the Austrian chemists are marked C.

The following is a summary of the more important matters referred to in this evidence, with the main conclusions which your Committee have drawn from them. The subject may naturally be divided into two parts, the chemical and the mechanical.

1. *Chemical Considerations.*

Under this head are included the manufacture of the gun-cotton itself, and the answers to such inquiries as those which refer to its liability, or non-liability, to deterioration by keeping, the possibility of its spontaneous decomposition, and the nature and effects of the products into which it is resolved on explosion.

As to the chemical nature of the material itself, Baron Lenk's gun-cotton differs from the gun-cotton generally made, in its complete conversion into a uniform chemical compound. It is well known to chemists that, when cotton is treated with mixtures of strong nitric and sulphuric acids, compounds may be obtained varying considerably in composition, though they all contain the elements of the nitric acid, and are all explosive. The most complete combination, or product of substitution, is that described by Mr. Hadow as $C_{36}H_{21}(9NO_4)O_{30}$, which is identical with that termed by the Austrian chemists Trinitrocellulose, $C_{12}H_7(3NO_4)O_{10}$. (C. 2.) This is of no use whatever for making collodion, but it is Baron Lenk's gun-cotton, and he secures its production by several precautions. Of these the most important are—

1st. The cleansing and perfect desiccation of the cotton, as a preliminary to its immersion in the acids.

2nd. The employment of the strongest acids attainable in commerce.

3rd. The steeping of the cotton in a fresh strong mixture of acids, after its first immersion and partial conversion into gun-cotton.

4th. The continuance of the steeping for forty-eight hours.

5th. The thorough purification of the gun-cotton so produced, from every trace of free acid. This is secured by its being washed in a stream of water for several weeks. Subsequently a weak solution of potash may be used, but this is not essential.

The prolonged continuance of these processes appears at first sight superfluous, but it is really essential; for each cotton-fibre is a long narrow tube, often twisted and even doubled up, and the acid has first to penetrate into the very furthest depths of these tubes, and afterwards has to be soaked out of them. Hence the necessity of time. It seems to have been mainly from want of these precautions that the gun-cotton experimented on by the French Commission gave irregular and unsatisfactory results. (C. 1.)

From the evidence before the Committee, it appears that this highest nitro-compound, when thoroughly free from acid, is not liable to some of the objections which have been urged against that mixture of compounds which has been usually employed for experiments on gun-cotton.

These advantages may be classed as follows:—

1st. It is of uniform composition, and thus the force of the gases generated on explosion may be accurately estimated. (C. 2.)

2nd. It will not ignite till raised to a temperature of at least 136° C. (277° F.), a heat which does not occur unless artificially produced by means which would render gunpowder itself liable to ignition. (C. 5.)

3rd. It is almost absolutely free from ash when exploded in a confined space.

4th. It has a very marked superiority in stability over other forms of gun-cotton. It has been kept unaltered for fifteen years, and is not liable to that spontaneous slow decomposition which is known to render lower products worthless after a short time. (C. 4, 6.) Yet there are still some reasons for suspecting that even the gun-cotton produced at the Imperial works suffers some gradual deterioration, especially when exposed to the sunlight. (A. 20, C. 3.)

The details of the process of manufacture at Hirtenberg are given at length in Mr. Abel's first report, in General von Lenk's replies (L. 21), and in a patent (No. 1090) taken out by Mr. Thomas Wood Gray, and sealed Oct. 10, 1862.

The course of proceeding recently adopted at the Royal Gunpowder Works, Waltham Abbey, is fully described in Mr. Abel's third memorandum. (A. 10–16.)

There is one part of the process not yet alluded to, and the value of which is more open to doubt, namely, the treatment of the gun-cotton with a solution of silicate of potash, commonly called water-glass. Mr. Abel (A. 15) and the Austrian chemists think lightly of it; but Baron Lenk considers that the amount of silica set free on the cotton by the carbonic acid of the atmosphere is really of service in retarding the combustion. He adds that some of the gun-cotton made at the Austrian Imperial Works has not been silicated at all, and some but imperfectly; but when the process has been thoroughly performed, he finds that the gun-cotton has increased permanently about 3 per cent. in weight. A piece of one of the samples left by the

General was indeed found to contain 2·33 per cent. of mineral matter, consisting chiefly of silica*.

Much apprehension has been felt about the effect of the gases produced by the explosion of gun-cotton. It has been stated that both nitrous fumes and prussic acid are among these gases, and that the one would corrode the gun, and the other poison the artillerymen. Now, though it is true that from some kinds of gun-cotton, or by some methods of decomposition, one or both of these gases may be produced, the results of the explosion of the Austrian gun-cotton, without access of air, are found by Karolyi to contain neither of these, but to consist of nitrogen, carbonic acid, carbonic oxide, water, and a little hydrogen, and light carburetted hydrogen. (C. 7.) These are comparatively innocuous; and it is distinctly in evidence that practically the gun is less injured by repeated charges of gun-cotton than of gunpowder, and that the men in casemates suffer less from its fumes. (L. 13.) The importance of this latter property in a fortress, or a ship, will be at once apparent.

It seems a disadvantage of this material as compared with gunpowder that it explodes at a lower temperature, possibly at 136° C (277° F.); but against the greater liability to accident arising from this cause may be set the greatly diminished risk of explosion during the process of manufacture, since the gun-cotton is always immersed in liquid, except in the final drying; and that may be performed, if desirable, at the ordinary temperature of the air. Again, if it should be considered advisable at any time, it may be stored in water, and only dried in small quantities when required for use.

The fact that gun-cotton is not injured by damp like gunpowder, is indeed one of its recommendations. It is not even so liable to absorb moisture from the atmosphere, 2 per cent. being the usual amount of hygroscopic moisture found in it; and should that quantity be increased through any extraordinary conditions of the air, the gun-cotton speedily parts with its excess of moisture when the air returns to its ordinary state of dryness. (A. 5 & 8.)

But a still more important chemical advantage which gun-cotton possesses, arises from its being perfectly resolved into gases on explosion, so that there is no smoke to obscure the sight of the soldier who is firing, or to point out his position to the enemy; and no residue left in the gun to be got rid of before another charge can be introduced.

2. *Mechanical Considerations.*

At the outset of this inquiry the Mechanical Members of the Committee found it difficult to believe that greater effects are produced by a given volume of gases generated from gun-cotton than by an equal volume of gases generated from gunpowder; nevertheless, from the facts as brought before the Committee, such contradiction would at first sight appear to exist.

The great waste of force in gunpowder constitutes an important difference between it and gun-cotton, in which there is no waste. According to the experiments of Bunsen and Schischkoff†, the waste in gunpowder is 68 per cent. of its own weight, and only 32 per cent. is useful. This 68 per cent. is not only waste in itself, but it wastes the power of the remaining 32 per cent. It wastes it mechanically, by using up a large portion of the mechanical force of the useful gases. The waste of gunpowder issues from the gun with much higher velocity than the projectile; and if it

* Two combustions of it, made by Dr. Gladstone, gave respectively 2·27 and 2·4 per cent. of ash. It was mainly insoluble silica in a state of very fine division, but acids dissolved out of it an appreciable amount of lime.

† Pogg. Annal. 4th Series, vol. xii. p. 131.

be remembered that in 100 lbs. of useful gunpowder this is 68 lbs., it will appear that a portion of the 32 lbs. of useful gunpowder gas must be employed in impelling a 68 lb. shot composed of the refuse of gunpowder itself.

There is yet another peculiar feature of gun-cotton: it can be exploded in any quantity instantaneously. This was once considered its great fault; but it was only a fault when we were ignorant of the means to make that velocity anything we pleased. General von Lenk has discovered the means of giving gun-cotton any velocity of explosion that is required, by merely varying the mechanical arrangements under which it is used. Gun-cotton in his hands has any speed of explosion, from 1 foot per second to 1 foot in $\frac{1}{1000}$ of a second, or to instantaneity. The instantaneous explosion of a large quantity of gun-cotton is made use of when it is required to produce destructive effects on the surrounding material. The slow combustion is made use of when it is required to produce manageable power, as in the case of gunnery. It is plain, therefore, that if we can explode a large mass instantaneously, we get out of the gases so exploded the greatest possible power, because all the gas is generated before motion commences, and this is the condition of maximum effect. It is found that the condition necessary to produce instantaneous and complete explosion is the absolute perfection of closeness of the chamber containing the gun-cotton. The reason of this is, that the first ignited gases must penetrate the whole mass of the cotton; and this they do (and create complete ignition throughout) only under pressure. This pressure need not be great. For example, a barrel-load of gun-cotton will produce little effect and very slow combustion when out of the barrel, but instantaneous and powerful explosion when shut up within it.

On the other hand, if we desire gun-cotton to produce mechanical work and not destruction of materials, we must provide for its slower combustion. It must be distributed and opened out mechanically, so as to occupy a larger space, and in this state it can be made to act even more slowly than gunpowder; and the exact limit for purposes of artillery General von Lenk has found by critical experiments. In general it is found that the proportion of 11 lbs. of gun-cotton, occupying 1 cubic foot of space, produces a greater force than gunpowder (of which from 50 to 60 lbs. occupy the same space), and a force of the nature required for ordinary artillery. But each gun and each kind of projectile requires a certain density of cartridge. Practically gun-cotton is most effective in guns when used as $\frac{1}{4}$ to $\frac{1}{3}$ weight of powder, and occupying a space of $1\frac{1}{10}$th of the length of the powder cartridge, and of such density that 11 lbs. occupy a cubic foot.

The mechanical structure of the cartridge is of high importance, as affecting its ignition. The cartridge is formed of a mechanical arrangement of spun cords; and the distribution of these, the place and manner of ignition, the form and proportion of the cartridge, all affect the time of complete ignition. (A. 19. L. 22.) It is by the complete mastery he has gained over all these minute points that General Lenk is enabled to give to the action of gun-cotton on the projectile any law of force he pleases.

Even at the present high price of cotton, its cost of production is said to be less than that of gunpowder, the price of quantities being compared which will produce equal effects. (L. 20.)

Practical Applications.

Gun-cotton is used for artillery in the form of thread or spun yarn. In this simple form it will conduct combustion slowly in the open air at a rate of not more than 1 foot per second. This thread is woven into a

texture or circular web. These webs are made of various diameters; and it is out of these webs that common rifle cartridges are made, merely by cutting them into the proper lengths, and enclosing them in stiff cylinders of paste-board, which form the cartridge. In this shape its combustion in the open air takes place at a speed of 10 feet per second. In these cylindrical webs it is also used to fill explosive shells, as it can be conveniently employed in this shape to pass in through the neck of the shell. Gun-cotton thread is spun into ropes in the usual way, up to 2 inches diameter, hollow in the centre. This is the form used for blasting and mining purposes; it combines great density with speedy explosion, and in this form it is conveniently coiled in casks and stowed in boxes. The gun-cotton yarn is used directly to form cartridges for large guns, by being wound round a bobbin, so as to form a spindle like that used in spinning-mills. The bobbin is a hollow tube of paper or wood. The object of the wooden rod is to secure in all cases the necessary length of chamber in the gun required for the most effective explosion. The gun-cotton circular web is enclosed in tubes of india-rubber cloth to form a match-line, in which form it is most convenient, and travels with speed and certainty.

Conveyance and storage of gun-cotton.—It results from the foregoing facts that 1 lb. of gun-cotton produces the effect of more than 3 lbs. of gunpowder in artillery. This is a material advantage, whether it be carried by men, by horses, or in waggons. It may be placed in store and preserved with great safety. (L. 7, & 16.) The danger from explosion does not arise until it is confined, as it simply burns intensely in the open air. It may become damp, and even perfectly wet without injury, and may be dried by mere exposure to the air. This is of great value in ships of war; and in case of danger from fire, the magazine may be submerged without injury.

Practical use in artillery.—It is easy to gather from the foregoing general facts how gun-cotton keeps the gun clean, and requires less windage, and therefore performs much better in continuous firing. In gunpowder there is 68 per cent. of refuse, or the matter of fouling. In gun-cotton there is no residuum, and therefore no fouling.

Experiments made by the Austrian Committee proved that 100 rounds could be fired with gun-cotton against 30 rounds of gunpowder.

In firing ordnance with gun-cotton, the gun does not heat to any important extent. Experiments showed that 100 rounds were fired with a 6-pounder in 34 minutes, and the gun was raised by gun-cotton to only 122° Fahrenheit, whilst 100 rounds with gunpowder took 100 minutes, and raised the temperature to such a degree that water was instantly evaporated. The firing with the gunpowder was therefore discontinued; but the rapid firing with the gun-cotton was continued up to 180 rounds without any inconvenience. (L. 9.) The absence of fouling allows all the mechanism of a gun to have more exactness than where allowance is made for fouling. The absence of smoke promotes rapid firing and exact aim.

The fact of smaller recoil from a gun charged with gun-cotton is established by direct experiment; its value is two-thirds of the recoil from gunpowder —the projectile effect being equal. (L. 5.) To understand this may not be easy. The waste of the solids of gunpowder accounts for one part of the saving, as in 100 lbs. of gunpowder 68 lbs. have to be projected in addition to the shot, and at much higher speed. The remainder General von Lenk attributes to the different law of combustion; but the fact is established.

The comparative advantage of gun-cotton and gunpowder for producing high velocities is shown in the following experiment with a Krupp's cast

steel gun, 6-pounder. An ordinary charge, 30 ounces powder, produced 1338 feet per second. A charge of $13\frac{1}{2}$ oz. gun-cotton produced 1563 feet.

The comparative advantage in shortness of gun is shown in the following experiments with a 12-pounder:—

	Charge.	Length of gun.	Velocity.
Gunpowder	49·0 oz.*	$13\frac{1}{2}$ calibres.	1400
Gun-cotton	15·9 ,,	10 ,,	1426
,, ...	17·0 ,,	9 ,,	1402

Advantage in weight of gun.—The fact of the recoil being less, in the ratio of 2 : 3, enables a less weight of gun to be employed as well as a shorter gun, without the disadvantage to practice arising from lightness of gun. (L. 5.)

Endurance of gun.—Bronze and cast iron guns have been fired 1000 rounds without in the least affecting the endurance of the gun.

Application to destructive explosions. Explosion of Shells.—From some unexplained difference in the action of gun-cotton, there is an extraordinary difference of result as compared with gunpowder; namely, the same shell is exploded by the same quantity of gas into more than double the number of pieces. This is partly to be accounted for by the greater velocity of explosion when the gun-cotton is confined very closely in very small spaces. It is also a peculiarity, that the stronger the shell the smaller the fragments into which it is broken. (L. 17.)

Mining uses.—The fact that the action of gun-cotton is violent and rapid in exact proportion to the resistance it encounters, tells us the secret of its far higher efficacy in mining than gunpowder. The stronger the rock the less gun-cotton comparatively with gunpowder is necessary for the effect; so much so that, while gun-cotton is stronger than powder as 3 to 1 in artillery, it is stronger in the proportion of 6·274 : 1 in a strong and solid rock, weight for weight. It is the hollow rope form which is used for blasting. Its power of splitting up the material can be regulated at will.

Against the gates of a city.—It is a well-known fact that a bag of gunpowder nailed on the gates of a city will blow them open. In this case gun-cotton would fail; a bag of gun-cotton exploded in the same way is powerless. If 1 ounce of gunpowder is exploded in scales the balance is thrown down; with an equal force of gun-cotton the scale-pan is not depressed. To blow up the gates of a city, a very few pounds of gun-cotton carried in the hand of a single man will be sufficient; only he must know its nature. In a bag it is harmless; exploded in a box it will shatter the gates to atoms.

Against the palisades of a fortification.—A small square box containing 25 lbs. merely flung down close to them, will open a passage for troops. In an actual experiment on palisades a foot diameter and 8 feet high, driven 3 feet into the ground, backed by a second row of 8 inches diameter, a box of 25 lbs. cut a clean opening 9 feet wide. On this three times the weight of gunpowder produced no effect whatever, except to blacken the piles.

Against bridges.—A strong bridge of oak, 12 inches scantling, 24 feet span, was shattered to atoms by a small box of 25 lbs. laid on its centre: the bridge was not broken, it was shivered.

Under water.—Two tiers of piles 10 inches thick, in water 13 feet deep, with stones between them, were blown up by a barrel of 100 lbs. gun-cotton placed 3 feet from the face, and 8 feet under water. It made a clean sweep through a radius of 15 feet, and raised the water 200 feet. In Venice, a

* Ordinary charge of powder.

barrel of 400 lbs. placed near a sloop in 10 feet water at 18 feet distance, shattered it to pieces and threw the fragments to a height of 400 feet.

All experiments made by the Austrian Artillery Committee were conducted on a grand scale—36 batteries of 6- and 12-pounders having been constructed for gun-cotton, and practised with that material. The reports of the Commissioners are all based on trials with ordnance from 6-pounders to 48-pounders smooth-bore and rifled cannon. The trials with small firearms have been comparatively few, and are not reported on. The trials for blasting and mining purposes were also made on a large scale by the Imperial Engineers Committee, and several reports have been made on the subject.

The Committee desire to put upon record their conviction that the subject has neither chemically nor mechanically received the thorough investigation which it deserves. There remain many exact measures still to be made, and many important data to be obtained. The phenomena attending the explosion of both gun-cotton and gunpowder have to be investigated, both as to the temperatures generated in the act of explosion, and the nature of the compounds which result from them under circumstances strictly analogous to those which occur in artillery practice; and until these are accurately ascertained, it is impossible to reconcile the apparent contradictions between the mechanical phenomena which result from the employment of gun-cotton gases and gunpowder gases, when employed to do the same kind of mechanical work.

APPENDIX.

I.—*System of Manufacture of Gun-cotton as carried on in the Imperial Austrian Establishment.* *By* F. A. Abel, *F.R.S.*

(1) The cotton employed is of superior quality, tolerably free from seed; it is carded loosely, twisted, and made up into skeins before conversion. The strands of the cotton composing the skeins are of two sizes—the larger being intended for cannon-cartridges, and the other for small-arm cartridges and bursters.

(2) *Preparatory Preparation of the Cotton.*—The cotton, made up into skeins weighing about 3 ounces each, is washed in a solution of pure carbonate of potassa of the specific gravity 1·02, being immersed in the boiling solution for a short time. Upon removal from the alkaline liquid, the skeins are placed in a centrifugal machine, by which the greater portion of the liquid is separated. The skeins are now washed in clear running water, either by allowing them to remain in it for three or four hours, or else by washing each skein by hand for a few minutes. They are then again worked in a centrifugal machine and afterwards dried—in summer by the rays of the sun, but during winter in a drying-house heated by air-pipes to between 30° and 38° C.; the latter plan usually takes four or five days.

(3) *Production of the Gun-cotton.*—The nitric acid employed has a spec. grav. of 1·53, and the sulphuric acid a spec. grav. of 1·82. They are mixed in the proportion of three parts by weight of sulphuric acid and one part of nitric acid.

Two skeins (about 6 ounces) of the cotton are immersed at one time in the mixed acids, and moved about for a few moments with iron paddles. They are then raised upon a grating above the level of the acids and submitted to gentle pressure; thence they are transferred to covered stone jars, each of

which receives six skeins of known weight. The jars are then weighed, some of the mixed acids being added if necessary, to bring the proportion of acids up to $10\frac{1}{2}$ lbs. to 1 lb. of cotton.

The jars are set aside for forty-eight hours in a cool place; in summer they should be placed in cold water. When that period has elapsed, the acid is separated from the cotton as far as possible by means of a centrifugal machine, as before described. The men working the machine are protected from the fumes of the acids by a wooden partition. The acids removed from the cotton are not used again in the preparation of gun-cotton.

The skeins of gun-cotton are at once removed from the centrifugal machine to perforated receptacles, which are immersed in a stream, where they are allowed to remain at least three weeks. Each skein is afterwards separately rinsed in the stream to remove mechanical impurities, and the water is then separated by the centrifugal machine.

The gun-cotton is next submitted to treatment with a solution of carbonate of potassa, as in the preliminary process, and again washed after the alkaline liquid has been expressed. When the skeins have been allowed to dry tolerably by simple exposure to air, they are placed in a large wooden tub containing a solution of silicate of soda, the temperature of which is about 15° C. This solution should have a specific gravity of 1·072, and is prepared as required from a solution of spec. grav. 1·216. The cotton remains one hour in the solution of silicate of soda, which is supposed to exercise two functions:—

(*a*) That of protecting the cotton by acting as a varnish upon the fibres.
(*b*) That of retarding its combustion.

Upon removal of the gun-cotton from the bath of water-glass, the liquid is partly expressed by hand, and afterwards more fully by means of the centrifugal machine. The skeins must then be thoroughly dried. They are afterwards immersed in running water for five or six hours, and each skein subsequently washed by hand. The water having been extracted by the centrifugal machine, the gun-cotton is removed to the drying-house, where it remains eight or ten days. Its manufacture is then completed.

The gun-cotton is packed in ordinary deal boxes lined with paper, and kept in dry magazines until required to be made into cartridges, &c.

Well-organized arrangements are employed for mixing the sulphuric and nitric acids, immersing the cotton, and for conducting the various other operations connected with the manufacture.

II.—*On the Composition, and some Properties, of Specimens of Gun-cotton prepared at the Austrian Government Works. By* F. A. Abel, *F.R.S.*

(4) Several specimens of gun-cotton prepared at the Imperial Factory at Hirtenberg near Vienna*, being the descriptions manufactured for cannon, for shells, and for small arms, were submitted to chemical examination, to determine the following points:—

(*a*) The proportion of hygroscopic moisture existing in them, under normal conditions.
(*b*) The composition of the different specimens of gun-cotton.
(*c*) The proportion and nature of their mineral constituents.

(5) I. The proportion of moisture expelled from the samples of gun-cotton,

* Several of these specimens were taken from ammunition, &c., which were being used at the time, for experimental practice, by the Austrian authorities.

by exposure to desiccation *in vacuo* over sulphuric acid, was very uniform. The specimens were examined both in the condition in which they were found on opening the parcel containing them, and after their exposure for some time to a temperate and moderately dry atmosphere. The mean proportion of hygroscopic moisture found in the gun-cotton was 2 per cent. Further experiments, relating to the hygroscopic properties of the gun-cotton, will be described hereafter.

(6) II. The composition of the specimens of Austrian gun-cotton, *i. e.* the proportion of hydrogen-atoms which had been replaced, in the original cotton, by hyponitric acid, was determined by the synthetical method first employed by Mr. Hadow, in his examination of the substitution-products obtained by the action of nitric acid upon cotton*. The dried specimens of gun-cotton were digested in the cold, for twenty-four hours, in an alcoholic solution of sulphhydride of potassium (KS, HS), prepared as described by Mr. Hadow; and the reduced cotton thus obtained in each case was thoroughly washed and dried. These products, after weighing, were proved to be free from nitrogen-compounds, by the ignition of portions with hydrate of potassa, when no indications of the existence of nitrogen in the specimens were obtained.

The percentage of cotton obtained by this synthetical method from four specimens of the gun-cotton were as follows:—

I. 55·20 per cent.
II. 55·07 per cent.
III. 55·13 per cent.
IV. 54·97 per cent.

These results show, as might have been predicted from the method of treatment of the cotton adopted, that the products obtained at the Austrian works consist, very uniformly, of the most highly explosive variety of gun-cotton, represented by the formula $C_{36} H_{21} O_{30}$, $9 NO_4$, as is shown by a comparison of the above numbers with Mr. Hadow's results, and with the theoretical percentage number:—

By synthesis. Cotton found in Austrian samples.	By synthesis. Hadow.	By analysis. Hadow.	By calculation.
55·20			
55·07	55·13	54·6 55·19	54·54
55·13			
54·97			

(7) III. The proportions of non-volatile matter or ash contained in the specimens of gun-cotton were determined in the following manner. The weighed gun-cotton was thoroughly moistened with distilled water; it was then cut into small fragments, and these were projected from time to time into a deep platinum vessel heated to dull redness. In this manner the gun-cotton was decomposed very gradually, the expulsion of the volatile portions being placed under such complete control as to exclude the possibility of any mechanical dispersion of portions of the ash. The heat was finally raised sufficiently to burn off any small quantity of residual carbon. From the ash thus obtained, the proportion was calculated upon the dry gun-cotton. Results obtained by this method from several determinations, with the same

* Quart. Journ. Chem. Society, vol. vii. p. 201.

specimen of gun-cotton, were closely concordant; but those furnished by different specimens varied slightly.

The following were the mean percentage results obtained:—

	Per cent.
(*a*) From a specimen of gun-cotton prepared for cannon	1·14
(*b*) From a specimen of gun-cotton prepared for small arms and shells	0·42
(*c*) From a specimen of gun-cotton prepared for blasting-purposes	1·90

(This specimen was slightly discolored, made from a lower quality of cotton, and not so perfectly washed as (*a*) and (*b*).)

The analysis of the ash furnished by the gun-cotton in these experiments, demonstrated the existence of some differences in the proportions of the several mineral constituents of the different specimens. The ash from (*a*) consisted of

Silicic acid........	0·71	per cent. in the cotton.
Lime	0·13	,, ,,
Magnesia	trace	
Oxide of iron......	trace	
Alkalies	0·25	,, ,,
Sulphuric acid	trace	

That furnished by specimen (*b*) consisted principally of lime; it contained besides traces of magnesia, oxide of iron, and alkalies, and only a small trace of silicic acid.

The ash from (*c*) consisted of—

Sand and clay	0·75	per cent. in the cotton.
Silicic acid, soluble ..	0·53	,, ,,
Lime	0·27	,, ,,
Alkalies	0·30	,, ,,
Magnesia	traces.	
Oxide of iron	traces.	
Sulphuric acid	traces.	

The ash was determined for comparison in a specimen of cotton obtained from the Austrian Works, which had been submitted to the preparatory purifying processes (treatment with carbonate of potassa and long-continued washing). The results obtained furnished a mean of 0·63 per cent. of ash, which consisted principally of lime and magnesia, and contained a small proportion of insoluble matter (clay and sand), traces of soluble silicic acid, and of alkalies.

The above determinations and analyses of the ash in the gun-cotton and in the unconverted cotton, show that no result of the slightest practical importance, in the direction supposed to be aimed at, is obtained by the treatment with solution of soluble glass, to which the purified gun-cotton is submitted, according to the Austrian system of manufacture.

It is evident that, by the washing in running water for five or six hours, and subsequent rinsing of each skein, *after* the treatment with silicate of soda, the proportion of the latter which had in the first instance been introduced into the cotton is again extracted, only traces being retained by the cotton, besides a very small proportion of silica in the form of pulverulent silicate of lime, resulting from the decomposition of the soluble glass by the lime-salts in the spring- or river-water. It will be observed that, in specimen (*b*) of gun-cotton, the proportion of non-volatile constituents is actually even less than that found in the purified but unconverted cotton,—a

fact which is evidently due to the solvent action of the acids upon portions of the mineral matter in the cotton. In the place of the comparatively large proportions of lime and magnesia in the *original* cotton, the product which, after separation from the acids by very long-continued washing, &c., has been submitted to treatment with soluble glass and again washed, contains some small quantities (necessarily variable in a product of manufacture) of impurities (clay and sand) derived from the water used, and of silicic acid in combination with lime and also with soda, minute quantities of the soluble glass having escaped removal or decomposition in the final washing process. Supposing that the maximum proportion of silicates (1 per cent.) found in the above determinations existed entirely in the form of soluble glass in the finished gun-cotton, a piece of twist 12 feet 10 inches in length, and of the size used for Artillery purposes ($\frac{1}{4}$ inch thick), would contain only one grain of soluble glass. It is evident therefore that no protective effect nor retardation in the explosion of the gun-cotton can result from the treatment with soluble glass to which it is submitted.

Experiments on the Hygroscopic Properties of the Austrian Gun-cotton.

(8) It has already been stated that the proportion of moisture contained, under normal conditions, in the specimens of Austrian gun-cotton was found to be very uniform, the mean proportion being fixed at 2 per cent. by the results of several experiments.

Some gun-cotton prepared from ordinary cotton-wool, and having the same composition as the Austrian samples—but not having been submitted to the preparatory or subsequent treatment with alkali, nor to the very long-continued washing—was examined with regard to its hygroscopic properties, in comparison with the Austrian gun-cotton. The proportion of moisture existing in the former, under ordinary conditions, was found to be almost identical with the average proportion in the Austrian samples.

Some experiments were instituted to ascertain the rate at which the Austrian gun-cotton would absorb moisture, on exposure to a damp atmosphere.

The specimens experimented with were first thoroughly dried *in vacuo* over sulphuric acid, and then exposed for successive periods, together with a shallow vessel containing water, under a capacious bell jar placed in a moderately warm room. The following results were obtained:—

Specimen.	Period of exposure to a damp atmosphere.					
	1 hr.	2 hrs.	4 hrs.	20 hrs.	30 hrs.	72 hrs.
No. 1	1·35	..	..	3·15	..	3·87
2	1·60	..	..	3·21	..	3·65
3	..	1·89	2·15	..	3·55	..
4	..	1·73	2·00	..	3·21	..
5	1·77	2·21	..	..	..	3·90

These results show that the rate of absorption of moisture by the gun-cotton is uniformly rapid up to the point where 2 per cent. (the normal proportion of hygroscopic moisture) have been absorbed, and that, when this point has been attained, the absorption of further moisture proceeds comparatively very slowly*. Several experiments were made to determine, as far as possible,

* Several determinations of the moisture in cotton rovings, both before and after treatment with alkali (and repeated washing), show that the proportion of hygroscopic moisture in the cotton amounts to between 6 and 7 per cent., this amount being reabsorbed by the dried cotton, within twenty-four hours, on exposure to air.

the *maximum* amount of moisture which the gun-cotton would absorb from a damp confined atmosphere. The great rapidity with which the specimens operated upon parted with the water absorbed, on exposure to the ordinary atmosphere, after the experiments had been proceeded with for some days, rendered the attainment of accurate numbers very difficult. The results, however, showed very definitely that no important increase in the amount of water absorbed took place when it had reached from 5·5 to 6 per cent. When these specimens had ceased to absorb moisture, they were, after the last weighing, exposed to the atmosphere at the ordinary temperature for one hour, and again weighed, when they were found to have parted with very nearly one-half of the total proportion of water absorbed. After further exposure to air for about four hours, the proportion of moisture retained had fallen to the average normal percentage (2 per cent.), and afterwards evinced no further tendency to decrease.

Two specimens were kept confined as described, together with a vessel of water, for several weeks in a moderately warm room. The water had then condensed, in numerous minute globules, upon the projecting filaments of the gun-cotton; the specimens were therefore very highly charged with moisture. In this condition they were exposed to the air at the ordinary temperature; within one hour and a half they contained only about 4·5 per cent. of moisture. After the lapse of a second similar period, the moisture had decreased to about 3 per cent. (3·16 in one specimen and 2·78 in the other). When again weighed, after a lapse of about four hours, the percentage of water had fallen, in both, to the average proportion.

Experiments corresponding to the above were made with the specimen of gun-cotton referred to above as having been prepared from common cotton-wool. The rate of absorption of moisture of this specimen was found to be decidedly more rapid than that of the Austrian gun-cotton; but they very closely resembled each other as regarded the rapidity with which they again parted, spontaneously, with the moisture absorbed from a damp atmosphere, and the average proportion ultimately retained. The differences noted in the rate of absorption of moisture between the two varieties of gun-cotton, is most probably due to the difference in their mechanical condition. Some of the specimens of Austrian gun-cotton used in these experiments were picked asunder, as loosely as possible, instead of being exposed in the form of twists; the difference thus established in the mechanical condition of the specimens did not affect, to any great extent, their relative hygroscopic properties. It was found impracticable, however, to reduce the gun-cotton rovings to the same mechanical condition as the gun-cotton prepared from finely carded wool.

It appears from the results above described, that—

(*a*) The proportion of moisture absorbed and retained, under ordinary circumstances, by the gun-cotton, is about double that contained under similar conditions in good gunpowder (which averages one per cent.).

(*b*) Gun-cotton possesses no tendency to absorb moisture beyond that proportion, unless in very damp situations; and even under those circumstances the proportion of moisture absorbed is limited. Moreover its capacity for retaining water (beyond the normal proportion) is so feeble that, however highly it may have accidentally become impregnated with moisture, it will return spontaneously to its original condition of dryness by simple exposure to the open air for a few hours. In these respects it possesses important advantages over gunpowder; for although the latter contains, under normal conditions, less moisture than gun-cotton, it exhibits great tendency to absorb

water from a moist atmosphere, which it continues to exert until it actually becomes pasty. Moreover gunpowder, when once damp, cannot be restored to a serviceable condition without being again submitted to the incorporating and subsequent processes.

III.—*Memorandum with reference to Experiments in progress bearing upon the Manufacture of Gun-cotton. By* F. A. Abel, *F.R.S.* (*Received Aug.* 23, 1863).

Experiments of a preliminary character.

(9) The experiments on a manufacturing scale, instituted on the Austrian system of preparing gun-cotton for military purposes, were preceded by an examination into some of the regulations laid down for the treatment of the cotton—the objects of these preliminary experiments being partly the attainment of direct proof of the necessity of a strict adherence to certain details (relating to the strength of the nitric acid, the duration of the treatment of the cotton with the mixed acids, and the rejection of the mixture after being once used), and partly the acquirement of experience in the treatment of the cotton.

It was important, before proceeding with these experiments, to determine upon some method, both expeditious and trustworthy, for submitting the products of the numerous experimental preparations of gun-cotton to comparative examination with the highest substitution-product, *i. e.* the Austrian gun-cotton.

Mr. Hadow's synthetical method of examination, which had been successfully employed in determining the composition of the Austrian gun-cotton, though valuable for finally controlling the composition of any particular product, is not sufficiently expeditious for the particular object in view, *i. e.* the examination of small samples from products of manufacture before their entire bulk is submitted to the final (purifying) processes *.

The first method tried for submitting the products of manufacture to comparative examination was as follows:—The weighed gun-cotton was soaked in water, the excess being afterwards expressed; and it was then placed in a glass tube about 18 inches long and open at both ends. Into one extremity was fitted a delivery-tube, dipping into mercury or water; the other was connected with a gas-holder containing nitrogen; the communication between the latter and the tube could be cut off by means of a stopcock. Air was expelled from the tube by means of the nitrogen, and the wet gun-cotton was then heated as quickly as possible by an Argand flame, the tube being slightly inclined. The gun-cotton was rapidly decomposed, though not with explosive violence; the gases issuing from the tube were collected and measured. The volume of gas furnished by different specimens of the Austrian

* Many experiments were instituted with this method of examination, and it was found that although the results obtained corresponded closely to theoretical requirements, when the starting-point in the examination was the gun-cotton, results of similar precision were not furnished by it when the original cotton itself was taken as the starting-point. That is to say, in commencing with a known weight of dry cotton, submitting it to proper treatment with the mixed acids, washing the product as carefully as possible, so as to avoid mechanical loss, drying the pure gun-cotton, digesting it with sulphhydride of potassium solution, and proceeding, with all possible care, exactly according to the prescriptions given by Mr. Hadow, the reduced cotton is always somewhat lower in amount than the cotton originally employed, the deficiency varying within the limits of 1 per cent. This deficiency is unquestionably due to the abstraction, by the mixed acids, of portions of the mineral constituents and of small proportions of organic matter from the cotton, and also, to a slight extent, to mechanical loss in the washing operations, which it appears impossible to guard against altogether.

gun-cotton, and of several specimens of gun-cotton-twist prepared according to the prescribed method, were sufficiently uniform to furnish reliable comparative results; but the liability of the glass tube to fracture during the application of heat, by the water present, led to the abandonment of this method of proceeding in favour of the following more simple one. A capacious glass globe, fitted with a stopcock and copper wires passing to the interior, is attached to an air-pump, which is also in communication with the upper end of a barometric tube. A weighed quantity of the gun-cotton is wrapped round a platinum wire, stretching from one copper wire in the globe to the other. The globe, being again attached to the air-pump, is exhausted until the mercury in the tube stands at about 29 inches. The gun-cotton is then inflamed by the aid of a voltaic current, and the depression of the column of mercury is noted when the apparatus has thoroughly cooled. By this method, perfectly concordant indications were obtained in employing different specimens of the Austrian gun-cotton, and of products prepared according to the precise method for producing the most explosive gun-cotton, which had furnished proper results when examined synthetically *.

Experiments have been made with quantities of cotton-wool varying from one to two ounces, to ascertain how far the long-protracted contact (for forty-eight hours) of the cotton with the mixed acids, as prescribed in the Austrian system, is essential to the complete conversion of the cotton-wool into the most explosive gun-cotton. The products obtained by immersion of the cotton even for thirty minutes were found to be almost perfectly converted; the volumes of gas furnished by them and their synthetical examination showed, however, that they still probably contained small quantities of unconverted cotton. Continuous immersion for twenty-four hours was found in all cases to furnish products completely up to the theoretical standard. Considering that the quantity of cotton immersed in one quantity of acid in the actual process of manufacture is much more considerable than that with which these experiments could be made, and that it is in the form of skeins of a somewhat compact roving or yarn, it appears a safe and not unnecessary precaution, in order to ensure perfect uniformity, to submit the cotton to as long a period of immersion as that adopted in Austria.

A considerable increase in outlay being involved in the employment, on a manufacturing scale, of a nitric acid of any specific gravity higher than 1·5, comparative experiments have been made on the production of gun-cotton with acid of that specific gravity, and of the spec. grav. 1·52 prescribed in the Austrian system †, both acids being mixed with the proper proportion of strong sulphuric acid. In all the experiments, the resulting products were found to be identical in their nature. Considering therefore that, according to the directions laid down, the mixed acids are only to be employed for the treatment of one quantity of cotton, there appears to be no advantage derivable from the employment of nitric acid of a higher specific gravity than 1·5.

Several experiments have been instituted for the purpose of ascertaining whether the rejection of the acids as of no further value, after the immersion in them of one quantity of cotton, was likely to be indispensable to the production of uniform results. In one instance, four equal quantities of the same

* In carrying on experiments to test the mode of examination, some interesting results were obtained bearing importantly upon the influence exerted over the rapidity and nature of decomposition of the gun-cotton by its position relatively to the source of heat, and by other variable conditions. These results have led to experiments now in progress.

† A sample of the nitric acid employed at Hirtenberg was collected on the spot; its specific gravity was found to be 1·515.

description of cotton were successively submitted for equal periods (forty-eight hours) to treatment with one and the same quantity of the mixed acids. The specific gravity of the latter, at the commencement of the experiment, was 1·82. The acid was separated from each quantity of the cotton at the expiration of the above period, by means of a small centrifugal machine. After two quantities of cotton had been immersed in the acid, its specific gravity was reduced to 1·81. The original mixed acids were examined by means of a standard solution of carbonate of soda; a known quantity of the mixture neutralized 148·3 measures of the solution. After immersion of the first quantity of cotton, 147·5 measures were neutralized by an equal quantity of the acid, and 146·3 measures after immersion of the second quantity of cotton. The reduction in the strength of the acid appeared therefore to be very uniform. The four products successively obtained were carefully purified and dried. The volumes of gas which they furnished upon ignition corresponded very closely with each other and with that obtained from a specimen of the Austrian gun-cotton.

In a second similar experiment, five different quantities of cotton were submitted successively to treatment for forty-eight hours with one and the same mixture of acids. The first three products furnished, upon comparative examination by the exploding method, almost identical results; the fourth and fifth afforded indications of less complete conversion. Examined synthetically, there was a difference of not quite 1 per cent. between the amount of recovered cotton obtained from the first and the fifth products.

The results of these experiments indicated, therefore, that products corresponding closely in composition can be obtained by the treatment of even more than two quantities of cotton successively with the same acid. It should be observed, however, that the above results were obtained with cotton in the unspun condition, and that the proportion borne by the mixed acids to the cotton was higher than that prescribed in the Austrian system of manufacture.

Experiments instituted upon a manufacturing scale at the Royal Gunpowder Works, Waltham Abbey.

(10) Very considerable difficulties were experienced in procuring the small quantity of cotton (two to three cwts.) required for these experiments, in a condition resembling sufficiently closely that employed at Hirtenberg, as its production in the form of the thick and the thin loose rovings, or yarn, necessitated some deviation from the ordinary method of spinning, which it was difficult to induce manufacturers to attempt without the promise of an extensive order. Eventually I succeeded, through the kind assistance of Mr. Whitworth, in obtaining the requisite quantity of coarse and fine yarn or roving, resembling closely in character, and quality of cotton, the specimens obtained from Hirtenberg, though in the subsequent operations with the coarse or thicker kind no inconsiderable proportion of it was found to be in a much less compact or more lightly twisted form than the Austrian samples. The comparatively open condition of this portion, and the impossibility of placing it under a sufficient strain to wind it compactly into cartridges, in consequence of the weakness of the yarn, must exert considerable influence upon the rapidity of its combustion in its employment in ordnance (as a few rough experiments at Waltham Abbey have indeed already shown); the gun-cotton prepared from these portions will therefore be carefully separated from the remainder, and will doubtless furnish instructive comparative re-

sults in the preliminary artillery experiments to be instituted with the gun-cotton.

The acids of the prescribed specific gravities were readily obtained at moderate prices—the sulphuric acid having a specific gravity of 1·84, and that of the nitric acid (a light amber-coloured acid) being 1·52.

The apparatus and implements employed, and the modes of conducting the various operations, were, as closely as practicable, in accordance with those in use at Hirtenberg—a slight deviation only, in the form or material of some of the implements, being adopted where it was decidedly advantageous and could not in any way influence the nature of the results. The following is an account of the details of manufacture:—

(11) a. *Preparation of the Cotton.*—The cotton was made up into skeins, those of the stout yarn weighing from four to six ounces each, and those of fine yarn from three to four ounces. It was then boiled for about fifteen minutes in a dilute solution of carbonate of potassa (of specific gravity 1·02, containing one pound of the salt to three gallons of water), and transferred thence to a centrifugal machine, which was maintained for about five minutes at a speed of 500 to 600 revolutions per minute. The alkaline liquid was thus very effectually separated from the cotton, which was then washed thoroughly, first by hand in a large tank, and afterwards by submersion in a stream for forty-eight hours. At the expiration of that period, the water was separated from the skeins by the aid of the centrifugal machine, and the purified cotton was then dried. Although the cotton was of good quality and very fairly cleaned from seed (being quite equal in these respects to the Austrian samples), it was found to sustain a loss of about 5 per cent. by the treatment with alkali and washing. The potassa solution in which it was boiled acquired a coffee colour. Portions of seed were still retained by the purified cotton, which were subsequently dissolved out perfectly by the acids.

(12) b. *Preparation of the Acids.*—The proportions of acids (three parts by weight, or 2·45 by volume, of sulphuric acid to one part of nitric acid) were weighed off and transferred to stoneware barrel-shaped vessels provided with taps, two of these receiving the sulphuric acid and a third the nitric acid. The barrels were so arranged upon a suitable table that the acids could be delivered from the taps into a deep and very capacious stoneware vessel, fitted with an iron lid with suitable apertures and a tap; this vessel was raised from the ground sufficiently to allow of the acids being transferred from it to well-stoppered stoneware bottles. While the acids were flowing slowly and uniformly from the barrels into the covered mixing-vessel, the resulting mixture was kept continuously stirred by means of a large iron paddle, and after they had been entirely transferred (which occupied about ten minutes), the stirring was continued for about twenty minutes before the mixture was drawn off into the bottles. The product of this operation had a specific gravity of 1·82. The elevation of temperature resulting from the mixture of the acids was considerable; in one observation the temperature of the acids before mixture was found to be 20° C., while that of the mixture, when complete, was 38° C. The acid thus prepared was set aside in a cool place, and never employed until at least twenty-four hours after the mixture had been made.

The mixing process and all the other operations with the acids were conducted in the open air, the workmen selecting their positions with reference to the direction of the wind. Thus no injurious effects, nor even inconvenience, were experienced by those employed.

(13) c. *Treatment of the Cotton with the mixed Acids.*—About twelve hours before immersion in the acids, the skeins to be operated upon at one time

(which had previously been dried in the air) were suspended in a capacious and well-ventilated drying-chamber, the temperature of which was maintained, for the above period, at not less than 49° C. They were then transferred, while in the chamber, to stoneware jars with tightly closing lids (the same as were used for keeping the cotton immersed in acid), and were allowed to become perfectly cold in these before submission to treatment with acid.

The vessels which were found most suitable for use in treating the cotton with the acid were large and rather deep stoneware pans: one, provided with an iron lid, contained the quantity of mixed acids required for the treatment of a certain number of skeins; a second, which was fitted with a perforated ledge of iron, and was surrounded by cold water, served for the treatment of the cotton, which was conducted as follows:—a proportion of the acid having been transferred to the second pan, two skeins were thoroughly immersed in it, and stirred about for two or three minutes; when saturated with acid they were raised upon the shelf and pressed together with the paddle, so as to allow the superfluous acid to flow off; the quantity of acid absorbed by these skeins was replaced in the pan by an addition of fresh acid, and further skeins were immersed, those which had drained being transferred to a jar while the freshly immersed ones were soaking. In this way the operation of immersion was continued until the whole of the skeins to be treated at one time had been transferred to the jars, six of the large yarn or nine of the fine being introduced into one of these.

The skeins were pressed down in the jars by means of the paddle, and sufficient acid was added just to cover the cotton completely. The jars were then closed and placed into vessels containing water, in a cool building, where they remained for forty-eight hours.

It was found an important precaution to keep the vessel in which the cotton was first immersed surrounded with water, especially in the warm season during which these experiments have been conducted, as the evolution of heat during the first action of the acids upon the cotton is considerable. The contents of the jars to which the gun-cotton was transferred were not found to become heated to any important extent, even when not surrounded by water. The proportion of acid to cotton said to be contained in the jars, as the process is carried out at Hirtenberg, is that of ten to one; but it was found necessary, in order to cover the cotton completely as directed, to employ at least fifteen parts of acid to one of cotton. This proportion would doubtless be much diminished if means were employed for compressing the cotton in the jars more highly than was the case in these experiments.

The precaution of adding a fresh supply of the acids to that which remains in the immersing-vessel after the withdrawal of each quantity of cotton treated, was proved by experiment to be of the greatest importance in securing the uniformity of the product. In one of the first operations, no fresh quantity of acid was added before immersing the skeins treated last. In other respects these skeins were submitted to precisely the same treatment as the remainder (*i. e.* an additional quantity of acid was added to them in the jar, they were allowed to remain for forty-eight hours, &c.). When examined synthetically, they furnished at least one-half per cent. more cotton than the skeins first treated in the same operation; and when fired in the proof-mortar, a decidedly lower range was obtained with the cotton last treated.

(14) d. *Purification of the Gun-cotton.*—At the expiration of forty-eight hours the jars were conveyed to a centrifugal machine, by which the principal quantity of acid was separated from the cotton. The machine employed at Hirtenberg for this purpose is made of copper, the one used by me was constructed entirely of iron, the sides of the revolving cylinder consisting of coarse iron-wire gauze, rendered sufficiently rigid by an iron framework. After each operation the machine was washed out with an abundant supply of water, and thus the corrosive action of the acids upon it has really been very trifling. The oxide dissolved by the acid when the skeins were placed in the machine was sufficient to colour the liquid, and also to stain the cotton in places, but these stains disappeared entirely in the first washing which the product received. The skeins were rapidly transferred, by means of an iron hook, to the machine, and the latter was then set in motion, at first slowly, and ultimately at a speed of 800 revolutions per minute. Within ten minutes the acid was so far separated from the cotton that the skeins were only damp.

Some precautions were necessary in effecting the first transfer to water of the skeins, with acid still clinging to them. If they were simply thrown into water so that the latter would penetrate them only gradually, the heat resulting from the union of the free acids and the water immediately established a violent action of the nitric acid upon the cotton, quantities of nitrous vapours being disengaged. At Hirtenberg the gun-cotton, when taken from the machine, is quickly placed under a small cascade, where its saturation with water is effected with very great rapidity. As this arrangement was not attainable at Waltham Abbey, the skeins, directly they were removed from the machine, were plunged singly, as rapidly as possible, and moved about violently, in a large body of water. They were then washed by hand in a stream until no acid taste whatever was perceptible in the cotton, and were afterwards immersed in the stream for a period of not less than forty-eight hours. For this purpose they were arranged in rows upon poles fixed in frames, which were so placed in the water that the skeins were in a vertical position, the water circulating among them freely. The current of the stream used at Waltham Abbey (at the only available place for these experiments) was not so rapid as could have been desired, and the dryness of the season had rendered it unusually sluggish; still it was sufficient to afford a continual change of the water surrounding the cotton. The character of this water is by no means such as to render it specially fitted for the purification of the gun-cotton. The bed of the stream is always thickly covered with luxuriant vegetable growth, and the water itself is consequently so highly charged with vegetable matter, that, although light was excluded as far as possible from the cotton during its immersion, the skeins became covered in many places, within a few days, by vegetable growth, which in time attached itself so firmly to the cotton as to be very difficult of removal by hand-washing.

The system of purification, as carried on at Hirtenberg, differs very considerably from that described in General Lenk's process as patented in this country. At the above-named establishment, the gun-cotton is in the first instance left in the stream for three weeks and upwards; it is afterwards washed in a dilute solution of carbonate of potassa, again washed in water, dried, and then treated with a solution of soluble glass. After this treatment it is dried, washed for six hours in the stream, and finally by hand.

In the patented process, it is directed that the gun-cotton in the first instance should be immersed in running water for *forty-eight* hours and up-

wards; it is not submitted to any treatment with carbonate of potassa, but is boiled, after the first washing, in a weak solution of soluble glass, and on its removal from this, without any intermediate desiccation, it is immersed in the stream for about six days.

The process of purification which I adopted differed from that in use at Hirtenberg only in the postponement of the long-continued washing until after treatment of the gun-cotton with alkali. At the expiration of forty-eight hours the skeins were removed from the stream, the water was separated from them in the centrifugal machine, and they were then boiled for a few minutes in a solution of carbonate of potassa of spec. grav. 1·02. Having been returned to the centrifugal machine, for the separation of the alkaline liquor, they were again placed in the washing-frames and left in the stream for a period of fourteen to eighteen days. On subsequent removal from the stream, each skein was washed by hand, to separate mechanical impurities, and one-half of each quantity of gun-cotton prepared was finally left in soak in distilled water for some hours. I found that, in consequence of the very large quantity of salts of lime in the river-water, the proportion of mineral matter in the gun-cotton was notably increased (it varied from 1 to 1·5 per cent.); this final washing was consequently adopted (there being a good supply of distilled water at hand) for the purpose of reducing the proportion of mineral matter added to the gun-cotton by the long-continued immersion in the stream. The gun-cotton thus finally purified was dried in the open air.

(15) c. *The treatment of the purified Gun-Cotton with Soluble Glass*, which forms one of the features of the Austrian system of manufacture, was stated by the officials at Hirtenberg to effect two important objects,—first, a retardation of the combustion of the gun-cotton; and secondly, its protection from atmospheric influences, by the formation of a coating upon the fibres of the cotton. In my account of the results of examination of the specimens of Austrian gun-cotton, I have entered fully into the reasons and facts which lead me to the conclusion that the treatment with soluble glass, the subsequent desiccation, and the final washing of the gun-cotton for five or six hours do not practically exert any effect upon the properties of the material, the only result being the addition to the mineral constituents of a small proportion of silicate of lime.

In General Lenk's process, as described in the English patent, the soluble glass is applied, as already stated, to the gun-cotton which, after the removal from the acids, has undergone no further treatment than an immersion in running water for forty-eight hours or thereabouts; when removed from the bath of silicate, the gun-cotton is not dried, but at once immersed for a period of six days in running water. It is at once obvious that this treatment cannot exert any effect upon the cotton, beyond possibly the neutralization of a minute trace of free acid still retained by it after the first washing. That the treatment with soluble glass is not intended to exert any other than a purifying effect upon the gun-cotton, appears also to have been understood by Professors Redtenbacher, Schrötter, and Schneider, in their inquiry into Baron Lenk's system of manufacture; for the only allusion which in their joint report they make to this point, is as follows, "the treatment with soluble glass has no influence on Baron Lenk's gun-cotton, it being previously free from acids."

In order to test, as nearly as possible in its integrity, the system of manufacture as carried on at Hirtenberg, it was determined to submit one-half of each quantity of gun-cotton produced in one operation to the treatment with

soluble glass, the other half being dried, as a finished product, after the immersion in distilled water above-mentioned.

The purified skeins to be treated with silicate of soda were first exposed to air until moderately dry, and then soaked for one hour in a boiling solution of the silicate, containing ten per cent. of that substance. When the excess of the liquid had been subsequently removed by means of the centrifugal machine, the gun-cotton still retained about 80 per cent. of the solution, which, by evaporation, left therefore about 8 per cent. of soluble glass in the material. The skeins were thoroughly dried in air, and then immersed in the stream for about forty-eight hours. A longer period of immersion was adopted than in use at Hirtenberg, on account of the comparatively sluggish current of the river. The skeins were finally washed by hand and dried, this operation completing the manufacture of the gun-cotton. A comparative examination of the ash of a "silicated" product with that of gun-cotton prepared at the same time, which had not undergone this treatment, exhibited a difference amounting to about one-fourth of the ash existing in the gun-cotton not treated: the latter furnished 1·45 per cent., the silicated left 1·85 per cent. of ash. The proportion of silica left in the gun-cotton was decidedly greater than that found in the Austrian specimens; but the portion not treated with soluble glass also contained a very notable amount of silica, derived from suspended matter in the water. A portion of gun-cotton treated with soluble glass has been washed for a few hours only, for comparative experiment.

(16) Artificial heat was not employed in drying any portion of the purified gun-cotton. This operation was accomplished by suspending the skeins during the day upon lines in the open air, or in a well-ventilated shed in wet weather and at night.

Miscellaneous Memoranda.

(17) 1. Samples of the products of manufacture obtained at Waltham Abbey have been submitted to synthetical examination, and furnished results as uniform as could have been anticipated, and corresponding to those demanded by the formula

$$C_{36}\left\{\begin{matrix}H_{21}\\ 9NO_4\end{matrix}\right\}O_{30}.$$

In the course of the manufacture the increase of weight actually sustained by the cotton has been directly determined, and it has been found that 100 lbs. of cotton, purified by the treatment with alkali, furnished about 177 pounds of gun-cotton (not silicated). The amount which theoretically 100 lbs. of cotton should furnish, of gun-cotton of the above composition, is 183·3 lbs. The discrepancy between these numbers is certainly not great when allowance is made for mechanical loss in the various washings, and for the foreign matters dissolved out of the cotton by the acids.

(18) 2. Several experiments have been instituted for the purpose of examining the characters of the product resulting from the treatment of cotton with the mixed acids which have already been used once. The quantities of cotton treated at one time, and the various steps in the manufacture, did not differ in any way from those adopted in the regular system in use. The product obtained from the coarse yarn, by means of the once-used acid, has been examined synthetically, and found to correspond very nearly in composition to gun-cotton of the formula

$$C_{36}\left\{\begin{matrix}H_{22}\\ 8NO_4\end{matrix}\right\}O_{30},$$

or the next lowest substitution-product to that obtained in the ordinary pro-

cess of manufacture. It was found, moreover, that the cotton yarn obtained in this experiment was very decidedly weaker (*i. e.* could sustain only considerably less strain) than the ordinary product—a result which must be ascribed to the greater predominance of sulphuric acid in the mixture which has been once used.

Experiments with this mixture and the *finer* yarn, furnished a different result to the foregoing. The products corresponded closely in composition to the theoretical result attained by the original or first employment of the acids. The rotting or weakening effect noticed above was much less apparent in these products than in the case of coarse yarn.

It would appear from these results that the mechanical condition of the cotton (*i. e.* the thickness of the yarn) exerts an important influence upon the nature of the product furnished by the once-used acid. Further operations are in progress in which this acid is employed; and the explosive effects of the resulting products will be carefully compared with those of the material obtained in the ordinary way.

(19) 3. No systematic artillery experiments or others illustrative of the explosive effects of gun-cotton prepared at Waltham Abbey have as yet been instituted, beyond a few trials of small charges in the mortar employed at the Gunpowder Works for purposes of proof. Even these results, however, as far as they go, are possessed of considerable interest, as demonstrating some of the most important points of difference between gun-cotton and gunpowder, when used in cannon, and as illustrating to some extent the value of the simple mechanical means devised by Baron Lenk for regulating the explosive action of the gun-cotton.

A quantity of the coarse roving, corresponding in weight to one-third of the proof-charge of gunpowder, was wound round a conical wooden plug, with the application only of a slight strain (equal to two ounces). The range obtained by this charge, or cartridge, was fully equal to that furnished by a full-proof charge of Enfield-rifle powder. The same weight of gun-cotton, wound upon a cone of the same dimensions, but kept during the winding under a strain of one pound, gave a range which was materially shorter than that furnished by the loosely wound charge, but quite equal to the average proof range (or three times the weight) of ordinary cannon-powder. Results agreeing with the above, and in very good accordance with each other, were obtained in frequent repetitions of those experiments.

The variation in composition of exceptional or special products, such as have been referred to in the preceding, manifested themselves in a corresponding variation in the range obtained with them, when tried under the same conditions as the ordinary products. Thus the skeins which in one particular operation had, as above described, been immersed finally, without addition of fresh acid, and which furnished synthetically a somewhat high proportion of cotton, did not yield so long a range as the ordinary products, nor as the first skeins obtained in the same operation. Again, the coarse yarn which had been treated with acid already once used, when wound into cartridges with a strain of two ounces on the yarn, did not furnish as long ranges as the ordinary products wound under a strain of one pound; and when made into cartridges under the latter conditions, the ranges it furnished were very considerably below the average results obtained with the ordinary product.

The absence of any appreciable residue in the mortar, and of any but the most trifling amount of smoke, only noticeable if watched for, were, it is hardly necessary to say, novel and important features in these few proof experiments.

(20) 4. Some observations made during the drying, and in the preservation

in store, of the finished gun-cotton, can hardly be passed over altogether without notice in this communication, though the precise nature and cause of the result which has manifested itself are still undetermined.

By far the larger proportion of the gun-cotton prepared at Waltham Abbey was dried in the open air, being exposed to strong daylight, and very frequently to powerful sunlight. When dry, it was packed into ammunition-boxes—large wooden cases containing an internal casing of tinned copper and with very tightly closing double lids. In opening some of these boxes containing gun-cotton, a faint but peculiar odour was accidentally observed, which was more distinct in some boxes than others. This observation led to the introduction of some pieces of litmus-paper among the skeins in different boxes, and these were found in some instances to change, after the lapse of time, to rose-colour, some merely at the edges, others more or less perfectly throughout. The change of colour was like that produced by carbonic acid upon litmus; and if the boxes were left open for some time, the paper gradually regained its original colour. If they were again closed for twenty-four hours or longer, the reaction upon the litmus-paper was again observed in those instances in which it had first been decidedly manifest, but it has been noticed to become gradually weaker. It was subsequently found that the gun-cotton, after it had been for some time exposed to strong daylight, and particularly to sunlight, in the open air, exhibited the same slight acidity, and that the reaction noticed in the boxes was always more marked in those which contained the gun-cotton most recently exposed for drying.

As above stated, no satisfactory explanation can as yet be afforded of the occasional exhibition of this slight acidity in the thoroughly purified gun-cotton under the circumstances described; to whatever causes it may be due, it appears evident, on a perusal of the report of Drs. Redtenbacher, Schrötter, and Schneider upon Baron Lenk's gun-cotton, that those chemists have noticed a similar occasional acidity as occurring in the Hirtenberg cotton, and, indeed, that this acidity has been dwelt upon as a cause for alarm by persons who have feared the spontaneous decomposition of the gun-cotton. The surmises as to its possible origin, put forward in the report above referred to, are, it must be confessed, not very satisfactory; neither, in the face of the extraordinary precautions adopted for effecting the complete purification of the gun-cotton, is the force of the following concluding paragraph of that part of the report which refers to this subject, very apparent:—"These acid traces should the less evoke surprise when we bear in mind that the gun-cotton in process of manufacture had been exposed for forty-eight hours to a strong acid bath; moreover, if the subject of comparison, viz. gunpowder, be tested with equal severity, similar evidence of chemical action will be forthcoming." It is in a material in which, in the first instance, the most delicate tests fail to detect the slightest evidence of free acid, that this slight acidity occasionally becomes evident. That exposure to light will, after some time, induce decomposition in the most carefully purified gun-cotton, is beyond dispute: as the latest of many proofs, which I myself have had of this, I may mention that some litmus-paper which has been for a few weeks exposed to light in a stoppered glass bottle, together with a piece of the Hirtenberg cotton, has become already perfectly bleached. But that an indication of change, such as has been dwelt upon above, should be afforded by so brief an exposure to light as five or six hours, and continue to be afforded after the cotton has been removed from light, appears to me to favour one of the conjectures put forward in the report referred to,—namely, that the gun-cotton may contain traces of high nitro-compounds which are much more liable to decomposition than it is itself

—a conjecture which may receive some support from the fact of the cotton being exposed for a very long period to the action of the acids. Under any circumstances, this is a matter which may be most intimately connected with the question of the keeping qualities of the gun-cotton, and which therefore requires the strictest investigation.

(21) 5. While referring to the question of the stability of gun-cotton, it may be important to record the following fact. It is pretty generally known that, soon after the discovery of gun-cotton by Schönbein in 1846, Messrs. Hall and Son, the extensive gunpowder-manufacturers at Faversham, entered upon the manufacture of this material, but were, after a time, so unfortunate as to have a very disastrous explosion of gun-cotton at their works, which, after a careful inquiry, was ascribed, by the jury and by all connected with the manufacture, to the spontaneous combustion of the material. The manufacture was stopped on the occurrence of this accident, and a considerable quantity of gun-cotton, which existed in the works, was buried by Messrs. Hall's direction (in July 1847), being simply thrown into a hole in the ground and covered up with earth. At my request, Messrs. Hall have been so kind as to have a sample of this gun-cotton, which has been buried for sixteen years, dug up and forwarded to me. This cotton, after being freed from dirt by washing, presented a discoloured appearance, and is stained in many places with oxide of iron, but it exhibits not the slightest evidence of having undergone change. The fibre is perfect throughout, and there is, as might have been anticipated, no trace of acidity manifest in any portion. It is not a rapidly burning gun-cotton, and leaves, upon ignition, a considerable carbonaceous residue; it does not therefore consist, or at any rate not entirely, of the most explosive substitution-product. A specimen, purified in the first instance by treatment with dilute hydrochloric acid, has been examined synthetically, and yielded 59·63 per cent. of cotton,—a result which agrees most closely to that which would be furnished by a product of the composition $C_{36}\left\{\begin{matrix}H_{23}\\ 7NO_4\end{matrix}\right\}O_{30}$ (which would furnish 60·66 per cent. of cotton). Messrs. Hall manufactured the gun-cotton by Schönbein's original process, which consisted, as far as I can learn, in the treatment of the cotton for about one hour with a mixture of one part of nitric acid of spec. grav. 1·45 to 1·5, and three parts of sulphuric acid of 1·85 spec. grav. The cotton was washed in running water until no acid was detected by litmus-paper, and afterwards dipped in a very weak solution of carbonate of potassa. The finished cotton was sometimes soaked in a weak solution of nitrate of potassa.

The examination of Messrs. Hall's buried gun-cotton appears to afford an interesting and important proof of the permanence of gun-cotton when excluded from air and light, but not protected from moisture—though it is necessary to bear in mind that this particular material does not correspond in composition to the regular Austrian product.

(22) 6. Referring once more, in conclusion, to the manufacturing experiments which form the main subject of this communication, it only remains to be stated that the very high price paid for the cotton for these experiments, the necessarily temporary arrangements, and the impossibility of fully economizing labour and material in carrying out the manufacture with such accommodation as could be furnished without any important outlay at Waltham Abbey, rendered the formation of any reliable estimate regarding the cost of the gun-cotton out of the question. But the scale upon which the manufacture was conducted has been quite sufficient to demonstrate most satisfactorily that, with a properly organized system of operation, the production of the gun-

cotton is certainly not more difficult or complicated, and is attended with considerably less risk of accident to the workmen and the manufacturing establishment, than the production of gunpowder.

IV.—*Information given by* Baron Lenk *on June* 22 *and July* 14, 1863.

1. *What weight of gun-cotton and gunpowder give equal effects?*—In accordance with experience, gun-cotton produces the same effect as three times its weight of gunpowder, which proportion, under certain circumstances, may be increased to six times its weight of gunpowder; for the effect of gun-cotton in proportion to gunpowder is the greater the more resistance is offered to the charge by the sides which enclose it, *and the less gas can escape at the beginning of the explosion.*

2. *What bulks of each give equal effect?*—The space required for a gun-cotton cartridge, to produce an equal effect, is scarcely half as large as that of a gunpowder cartridge; and it is only made equally large or slightly larger, if secondary circumstances should demand it.

3. *Is the effect more constant with gun-cotton or with gunpowder.*—The effect of small fire-arms and of artillery in general is considerably more uniform and constant with the use of gun-cotton than with gunpowder, provided the proper charge and cartridge has been taken.

That superiority gun-cotton partly owes to the chemical process by which I have produced it, and partly to the uniform formation of the cartridge, which can only be attained by its regular texture, using it in the shape of cotton-yarn.

4. *Which admits of more precise aim?*—On account of the more constant effect of gun-cotton, and because its use prevents fouling of the gun, which further admits to reduce the space between shot and barrel, and on account of less heating of the gun, as well as by the uniform position of the cartridge, there must be a more precise aim of shot with gun-cotton—which, moreover, has been fully proved by experience.

5. *Which occasions least recoil?*—Chiefly on account of the smaller space of time the projectile requires to pass through the barrel of a gun to attain a certain initial velocity, the recoil of the gun is less than with the use of gunpowder. It may be stated that, by the official trials of the Commissioners in the year 1860, the recoil of the gun with gun-cotton was found to be 0·68 of that with gunpowder.

6. *What is the relative effect as to fouling?*—Except an extremely small residuum of carbon, there is no deposit with the use of gun-cotton. The barrel of a gun requires no cleaning out; there is no chemical effect upon cast- and wrought-iron, steel, or bronze barrels by using gun-cotton cartridges.

7. *Is gun-cotton liable to decay when stored?*—Gun-cotton has been stored like gunpowder for twelve years, usually packed in wooden boxes; and no trace of alteration has been discovered. My own experiments go back as far as 1846, and have given most favourable results in this respect.

8. *How is it affected by water or damp?*—Gun-cotton placed under water is unalterable. By the transformation of ordinary cotton into gun-cotton, it loses the greater part of its hygroscopic property, so that gun-cotton, properly manufactured, resists the influence of damp much better than gunpowder; and moreover it cannot, like gunpowder, get permanently spoiled thereby. Gun-cotton, if dried in the open air, contains 2 per cent. moisture; ordinary cotton about 6 per cent. Gun-cotton, placed in a room completely saturated with

moisture, after thirty-three days of exposure contained 8 per cent. moisture, whilst under the same circumstances gunpowder was saturated with 79·9 per cent. of water; some weeks afterwards the whole saltpetre of the gunpowder was converted into a concentrated solution of saltpetre, whilst gun-cotton took no more than 8 per cent. of water as a maximum saturation.

9. *Which admits of most rapid firing?*—The gun being heated considerably less by using cotton-cartridges, the absence of a noteworthy residuum and smoke admits of a more easy manipulation and sighting of the gun, and thereby secures a more continuous and rapid fire.

It may be stated that 100 rounds with gun-cotton were fired in thirty-four minutes, and the barrel was heated to fifty degrees Cent.; whilst 100 rounds with gunpowder-cartridge in 100 minutes heated the gun so much that water dropped on the barrel immediately evaporated with noise, though three times as much time was required with the powder charges. The Commissioners continued the trials with gun-cotton up to 180 rounds without any danger from heating being apprehended, whilst the Commissioners thought it advisable, for the sake of safety, not to continue firing with powder charges under the above circumstances.

10. *What effect has gun-cotton on the coolness and cleanness of the gun?*—It has been already mentioned that, with the use of gun-cotton, fire-arms remain considerably cooler than with gunpowder; and the slight residuum has no influence upon the effect of the gun.

11. *How far is it adapted for breech-loading.*—There being no fouling of the gun, it follows that with the use of breech-loaders the construction of the breech may be kept quite tight.

12. *How is it for precision of aim?*—Under all circumstances the aim is not disturbed or interrupted, there being no smoke attending the discharge of the gun.

13. *Has it any special advantages in forts, ships, and casemates?*—From many experiments, but especially from the official trials made in the casemates of the fortress of Comorn in the year 1853, it results that under circumstances which would render the firing with powder difficult or even impossible, there was no trouble or molestation in any way to those serving the guns with the use of gun-cotton cartridges.

The trials in the fortress of Comorn were made in casemates, ventilation being intentionally obviated. After fifteen rounds with powder cartridges, further sighting of the gun was impossible; after forty-six rounds, one of the men serving the gun fell into convulsions of suffocation; a second man being ordered in the place of the first disabled man, got immediately sick on entering the casemate; the rest of the men were more or less stupefied; it was necessary to stop firing after fifty rounds given in eighty minutes. By using gun-cotton cartridges, on the contrary, after fifty rounds the men serving the gun felt not the least molestation, and the aim was always clearly visible.

14. *How is it adapted for mining?*—The more accelerated effect of gun-cotton, and the possibility of enclosing in the same space more than double the quantity of gases, especially direct us to employ gun-cotton where it is desired to attain an energetic effect for mining-purposes, for example, to secure harbours by means of sea-mines.

15. *What is the relative danger of manufacture?*—In the manufacture of gun-cotton every manipulation, up to its final accomplishment, is without any danger whatever, whilst with the manufacture of gunpowder danger of explosion exists from the beginning of the operation.

16. *What is the comparative risk in conveyance?*—The smaller weight of gun-cotton, as well as the smaller volume of it for an equal effect, favours the conveyance of gun-cotton considerably; and it may be taken moreover into consideration that the dangerous "getting to dust" of powder cannot take place with gun-cotton.

The transport of gun-cotton to the most distant parts of the empire of Austria under intentionally difficult circumstances, has always been effected without difficulty.

17. *How is it adapted for shells?*—Shells filled with gun-cotton hold a considerably larger quantity of material for the production of gases; at the same time, it is in the nature of both compounds that gun-cotton developes far quicker the gases of combustion than gunpowder; for this reason, shells filled with gun-cotton burst into at least double the number of pieces.

18. *Is it liable to spontaneous explosion?*—From the last Report, dated June 1863, of the Professors of Chemistry appointed by the Minister for War to report on that subject, and to give their opinion, and which is submitted to you, the apprehension of self-explosion has in no way any foundation whatever.

Without direct ignition, gun-cotton may detonate between iron and iron if a heavy blow be struck; but it is known that only that part explodes which was hit, without communicating ignition to the surrounding particles. If, however, even with an iron hammer, gun-cotton be struck a heavy blow upon bronze or other soft metals, or upon stone, no detonation can take place. In every report of the Austrian Empire Commissioners, that subject was considered and disposed of as not impairing the safety of manipulation.

19. *How far is it possible to regulate its explosive power?*—It has been established by experience that it is possible to moderate the force of gun-cotton within very extensive limits, and thereby to suit it to the different purposes without having ground for apprehension that variable effects would be the consequence; that valuable property of gun-cotton, however, requires that the trials be made under the superintendence of an expert, which will secure the desired effects to a certainty.

20. *What is its cost of manufacture?*—Supposing quantities which would produce equal effects, then its cost is considerably less than that of gunpowder; under ordinary circumstances and normal prices of cotton, the cost of manufacture of gun-cotton is under fourteen pence per pound, but at the present high price of raw cotton its cost will be under twenty pence per pound weight*.

21. *Give us what in your opinion are the essential points in the manufacture of gun-cotton.*

a. *Cotton.*—Any sort of cotton may be used for the production of gun-cotton, provided it be tolerably free from seed-capsules and oleaginous matter. Absence of the latter is indeed imperative; hence factory cotton, as ordinarily obtained, must be digested in a weak alkaline solution, as is usual in such cases.

Other forms of lignine can be substituted for cotton to produce an explosive material—viz. flax, hemp, bog-grass, maize, straw, rags, sawdust, &c. I have given rules so as to meet the case of either of these; however, it is only in some extraordinary cases that any of these materials are to be preferred to cotton; further, ulterior applications of the explosive material are much facilitated by the device of *spinning* into threads.

* Baron Lenk subsequently reduced this estimate.

b. *Nitric acid.*—The nitric acid employed must be in the highest possible degree of concentration; and here the remark should be made, that an impurity of hyponitric acid imparted to the acid by concentration, and which is difficult to eliminate, does not prejudice the acid for this special application.

c. *Sulphuric acid.*—The ordinary commercial sulphuric acid of spec. grav. 1·84 answers perfectly.

d. *Mixture of the acids.*—This consists of *one part by weight of nitric acid, and three parts (weight) sulphuric acid,*—assuming the nitric acid employed to possess an average specific gravity of 1·485. If, however, the specific gravity should differ from the above, then cognizance of the amount of anhydrous acid supplies the data necessary for regulating the mixture.

The mixture is effected by means of an apparatus represented by fig. 1.* The vessel C is filled with the predetermined quantity (equivalent to the required weight) of nitric acid; B and D with sulphuric acid. This being done, the acids from the three vessels are allowed to run very slowly into F, in which is an agitator T, set in motion by the handle L. As soon as a portion of the two acids has been mingled in this manner, the mixture is allowed to run from F to G, and the operation resumed as before.

The reservoir G being completely filled, its contents must be set aside in closed vessels. It is advantageous to preserve the mixed acids a considerable time in the above vessels; in no case must the mixture be used until it has become quite cold.

e. *Process of steeping.*—Cotton-wool ordinarily absorbs about 6 per cent. of atmospheric moisture, which must be dissipated in a drying-room heated to 95° F. previous to dipping the cotton.

Steeping is effected in an apparatus represented by figs. 2, 2*a*, and 2*b*. The apparatus, during the process, is kept *cool* by a constant change of cold water poured into the vessel F. The chamber A contains a store of acid, B sixty pounds of the acid mixture, D represents the vessel in which the cotton is stored after dipping is accomplished. Two skeins (about 3 ounces) of dried cotton are dipped at one operation in the mixture contained in B, the spatula G being used to effect, by pressure, complete incorporation between acid and cotton; in the next place, the cotton is to be removed from the bath, laid upon the rack C, and pressed to such extent that the amount of mixed acids left absorbed by the cotton be in the ratio of $10\frac{1}{2}$ *lbs. of the former to* 1 *lb. of the latter.* The cotton being now lifted into the vessel D, this is to be filled with mixed acids, and the portion of acid absorbed made good by means of the tared spoon E, in such manner that the surface in B may always maintain the same level for every additional portion of cotton dipped.

The vessel D filled in the manner prescribed, is at length set aside, the due proportion of its contents being regulated, if necessary: the regulation is easily accomplished after a little practice, but it is seldom requisite. The cotton is next compressed by the handle H in such manner that it is wholly covered by acid, to the further action of which it is left exposed for the space of forty-eight hours; it must be cooled during that exposure, thus guarding against the violent action of the acids resulting in decomposition.

f. *Removal of acid from the gun-cotton.*—This is performed by means of a centrifugal machine, the drum of which is of copper, a material which lasts a considerable time; after this manipulation, there still remain 3 lbs. of acid in the gun-cotton manufactured from 1 lb. of ordinary cotton. This must be got rid of by rapid water affusion applied in some convenient manner.

* This refers to a drawing exhibited at the time. See Plate III.

Mere affusion, however, does not suffice to get rid of all the adherent acid, hence the cotton must remain for a yet *longer* period in a stream of water, natural or artificial.

g. *Impregnation of gun-cotton with soluble glass.*—The object of this process is to close the pores of the gun-cotton fibre by silica precipitated within them, by which the velocity of explosion of gun-cotton is hereafter retarded; moreover any lingering traces of acid that may remain are neutralized by combination with soda liberated from the soluble glass. This operation is performed by means of a centrifugal machine, into which a central tube passes for supplying the glass solution. By this arrangement the liquid is driven in very minute division through the gun-cotton; the glass solution employed has a density of 12° Baumé. The material having been treated as described, has next to be dried by atmospheric exposure: as drying proceeds, decomposition of the soluble glass goes on. Atmospheric carbonic acid uniting with soda, forms carbonate of soda, whilst silica is precipitated.

The carbonate of soda thus produced being soluble in water, can be got rid of hereafter by washing, whereas the precipitated silicic acid not being soluble, remains attached to the cotton fibres, protecting them from decomposition under atmospheric influences, however high the temperature may be.

h. *Treatment with soap.*—For many purposes it is desirable to retain the fibres of gun-cotton soft, in order to guard against the contingency of explosion from very violent friction, gun-cotton being somewhat harsh to the touch.

This is readily effected by dipping the material, already treated with soluble glass and washed, previous to final drying, into a soap ley, the excess of which is to be hereafter squeezed out, and the gun-cotton finally dried.

22. *Have you any special information to give the Committee respecting the practical applications of gun-cotton?*

a. *In general.*—The proper utilization of gun-cotton presupposes a thorough knowledge of the nature of its energy and the bearing of its mechanical advantages, in order that the object proposed may be gained through a favourable choice of circumstances. These influences are more perceptible with gun-cotton than with gunpowder, inasmuch as gun-cotton admits of variation from a point of *inefficiency* to one of *highest energy*.

Ignited in an open space (*i. e.* not under pressure), the explosive effect of gun-cotton is trifling, very much less than that of gunpowder. Ignited in spaces more or less closed, then in proportion as the closure is perfect does the explosion assimilate itself to that of gunpowder, the force of which under certain circumstances it considerably surpasses; *i. e.* it is dependent on the resistance met with. The maximum of the explosive effect of gun-cotton is attained when the charge is so regulated, as to dimensions and form, that the whole of it becomes ignited before the yielding of any side of a vessel in which it is enclosed.

The products of combustion of gun-cotton are wholly gaseous, whereas gunpowder by combustion yields only 31 per cent. of gas, whence it would seem that the energy of a charge of gunpowder should be nearly equalled by a charge of gun-cotton only one-third of its weight. The available power of one part of gun-cotton by weight, may, under certain circumstances, be raised to the effect of six parts by weight of gunpowder.

b. *Application of gun-cotton as a charge for smooth-bore guns.*—The standard of reference was furnished by experiments conducted with a twelve-pounder bronze field piece, which gave results as follows:—

The weight of shot, solid round, used was 12 lbs.
Diameter of shot 4·5 inches. (English weight and measure.)
Diameter of bore for gun-cotton 4·56 inches.
Diameter of bore for gunpowder 4·67 inches.

Result.	Gun. No.	Gun. Length of Bore.	Cartridges. Material of Charge.	Cartridges. Length.	Initial velocity.	General Observations.
I.		$13\frac{1}{2}$ calibres.	Powder 3 lbs. 1 oz.	7·5 in.	1400 ft.	Normal.
II.	2	$11\frac{1}{2}$ "	Gun-cotton. 13·6 oz.	5·1	1375	Cartridges slightly compressed, filling the whole space.
III.	"	$11\frac{1}{2}$ "	" 14·8	"	1407	
IV.	3	$10\frac{1}{2}$ "	" 13·6	"	1358	
V.	1	$11\frac{1}{2}$ "	" 14·8	8·3	1400	Hollow cartridges represented at Plate II. fig. 2.
VI.	1	10 "	" 15·9	"	1426	
VII.	1	9 "	" 17·0	"	1402	

The normal performance of ordinary powder-guns gives result I., as compared with gun-cotton. With gun-cotton, when compressed charges were used, each of 13·6 oz., result II., gun 2; the gun was not injured; while with 14·8 oz. of charge, after a few rounds, a considerable enlargement of the bore, where the shot lies, took place. A similar result happened to a second gun, No. 3, even with a charge of 13·6 oz., after the first few shots.

When one of the enlarged cartridges, represented at Pl. II., fig. 2, was used, occupying 1·1 of the powder-space, the gun's endurance was perfect, and no loss of effect was sustained, and its practice remained good, as proved by results set forth at III. and V., since *equal charges* in *very different spaces* (*i. e.* in the ratio of 5 to 8) still produced equal results.

In proportion as the tube is shorter, an increased charge is required (shown by results V., VI., VII.); yet the effect of a normal powder-gun and charge may be attained by a tube shortened from $13\frac{1}{2}$ to 9 calibres: it follows that guns to be used with gun-cotton may be constructed much shorter than if intended to be charged with gunpowder*.

With the largest charge used, *i. e.* 17 ounces, about 1000 shots were fired from the same gun, without affecting the piece in the slightest—an endurance very satisfactory, and considerably greater than has been experienced with gunpowder.

This experiment was further continued for arriving at results by empirical means as to the strength of metal in various parts of the tube.

The original tube, formed as depicted at Pl. I. fig. 2, was gradually turned off until it assumed the shape figured in broken lines, but without any disadvantageous effect. The metallic strength of 3·7 inches close behind the seat of the ball, where, according to experience, the greatest strain takes place, and 1″·6 at the muzzle, were so moderate that for practical uses no further diminution was desirable; hence the experiments in this respect were discontinued.

Finally, I turned my attention to the object of flattening the trajectory of projectiles with this gun, and succeeded to such an extent that a projectile fired from the gun horizontally pointed at targets set up at 100 yards from each other as far as 1200 yards struck at an *even height* at 3 feet from the ground, and fell *without ricochet* at about 3200 yards.

An experiment made with a Krupp cast-steel 6-pounder, demonstrated

* No details are given as to precision.

that with harder and more resisting metal than bronze, the great power of gun-cotton might unhesitatingly be made use of to obtain a more energetic projectile force than would have been compatible with the use of gunpowder.

The results are as follows:—

A Krupp 6-pounder, cast steel, charged with 30 oz. of normal powder	1338 feet per second initial velocity of shot.
A Krupp 6-pounder, cast steel, charged with $13\frac{1}{2}$ oz. of gun-cotton	1563 feet per second initial velocity of shot.

In practice it is necessary with the use of gun-cotton to reduce the "windage" to a minimum; otherwise larger charges must be used, and with no corresponding advantage.

c. *Application of gun-cotton to rifled ordnance.*—The time may have arrived for breech-loaders, which have lately come into use under such good auspices, to be set aside in favour of muzzle-loaders, for the service of which gun-cotton offers such facilities, because of its leaving no solid residue after combustion, and because windage admits of reduction to a minimum.

The method of determining the condition of charge differs from the data given for smooth bores, in so far that the vehemence of explosion may be decreased by mechanical means—such as variation of length of chamber, regulating the mode of ignition so as to attain a sufficiently favourable condition of starting of the projectile from rest. This result was easily achieved (as demonstrated by experiments conducted in Austria) within the degrees of velocity hitherto deemed sufficient, as by the gun shown, Pl. I. fig. 1, and cartridges, Pl. II. fig. 1.

To what extent these deductions may hold good at higher velocities, must be determined by further experiments, which may be expected, judging from present data, to give favourable results.

The Austrian breech-loading guns (cast iron) of three service calibres (6, 12, and 24-pounders charged with 13, 30, and 60 lbs. weight projectiles respectively) answer perfectly when charged with gun-cotton, provided the chambers are enlarged to 1·1 of the original capacity for powder. For larger charges, cartridges made in the form of a hollow rope, similar to those used for blasting, would answer; however, I have to remark that it is more necessary in rifled than in smooth-bore guns to reduce the windage to a minimum; this, on account of the surprising exactness of work in English factories, would be easy of accomplishment, and would raise the effect of gun-cotton. Experiments performed with a cast-steel gun of 3 inches diameter, weighing only 50 lbs., firing hollow projectiles with effect to 3000 yards, demonstrate that, on account of the short length of tube necessary and the slight recoil, very light pieces can be made, Pl. I. fig. 3; the carriage was about 40 lbs. weight.

d. *Application of gun-cotton to small arms.*—In this respect it is important to observe that the plasters used with the old round-ball rifles were completely torn so long as short cartridges were used. When I elongated the cartridges the plasters resisted perfectly, and practice was very accurate; hence it is demonstrated that *length* is a very important element in the construction of small-arm cartridges. Experiment only can determine the *proper* length.

One circumstance is not to be lost sight of—that with a *very* long cartridge the *ignition* of it in proper time may be difficult to achieve. Practice in the application of mechanical means is requisite to secure the proper explosion of long cartridges by igniting them *well* in front. Lastly, experience proves that in small-arm cartridges *separation* of the cotton into several layers, by the

interposition of paper, influences the result. Small-arm cartridges which have answered best are composed of three layers of flat woven gun-cotton with paper interposed. For the small-bore long range rifles used in England, the cartridges most suitable may be those represented at Pl. II. fig. 3, the precise dimensions of them being fixed experimentally. On the 4th and 5th of July 1863, there was a preliminary trial at Manchester, during which it was found that no distortion of the projectiles ensued even when the proper conditions of charge were departed from by using too heavy charges.

e. *Application of gun-cotton to purposes of mining.*—Gun-cotton is more appropriate to this use than gunpowder, which it surpasses in proportion as the mass to be blasted is more compact. Assuming a solid rock to be blasted, and that the proper condition of charge together with the proper distribution of holes have both been heeded, the relative proportions of gun-cotton and of gunpowder for producing an equal effect are 1 gun-cotton to 6·274 gunpowder (weight by weight), whilst the relative proportions for wall-blasting (masonry) are 1 gun-cotton to 2·25 gunpowder; however, here the point must be noted, that when these experiments were performed the *best shape* of charge had not been determined. According to experiments more recently conducted, the form of charge for blasting which best answers is that of a *hollow twisted rope*, according to sample; the operation of charging is rendered thus very easy and safe—wooden tamping-rods being used until the charge is covered. According to repeated experiments, the strongest friction of gun-cotton between stone is unattended with the slightest danger. For large charges, it is to be remembered that *complete* ignition is more difficult than the complete ignition of large powder charges; to accomplish this result satisfactorily for mining-purposes, it is indispensable to fasten up the gun-cotton in *tightly closed vessels*—which afford the necessary resistance, *not yielding until the whole mass of gun-cotton has become ignited.* Experiments have proved that little barrels with strong hoops answer best. The proper construction of these restraining cases can be learned experimentally from models, when it will be remarked that *no smoke* results from explosion, and *very little fire* is seen.

As a charge for hollow projectiles, gun-cotton substituted for gunpowder will produce similar effects; but then the space of shell is only *partly* filled, even when the bursting powder charge is raised to its maximum. An increased charge of gun-cotton may be employed with advantage, which thus, in comparison with gunpowder, will give an additional effect, partly referable to additional material used, and partly to the occurrence of a more rapid explosion.

With projectiles having very small holes for filling, the accompanying samples were used, because of the ease with which filling could be conducted. When projectiles with cylindrical bore, capable of being thrown open, have to be filled, it would be advisable to insert cylindrical charges of gun-cotton previously compressed. A soft layer of felt is recommended to be laid interiorly against the base of the projectile—though this precaution does not seem to be imperative, no premature bursting having taken place in the course of any experiments.

f. *Application to fuse-purposes.*—For fuses gun-cotton is woven (according to pattern given), then steeped in saltpetre and covered with a jacket of india-rubber. In this manner the progress of combustion is rapid (over 30 feet per second); the line will bear considerable pressure, and may even be folded crossways without fear of the fire leaping from one fold to the other.

If ordinary gun-cotton thread be fired in a train loosely, ignition is very slow, about 1 foot per second.

V.—*Extracts from a Report on* Baron LENK's *Gun-cotton, by* Professors Dr. REDTENBACHER, Dr. SCHRÖTTER, *and* Dr. SCHNEIDER, *to* His Excellency Field-Marshal JOHANN FREIHERR KEMPEN VON FICHTENSTAMM, *President of the Royal Imperial Commission on Gun-cotton, June* 1863.

(1) "*Difference between the French Gun-Cotton and* Baron Lenk's.—According to the method pursued by the French Commission, the raw cotton was immersed in the acid mixture for one hour. Baron Lenk leaves his cotton forty-eight hours in the acid bath. The French cotton was afterwards dipped in running water for an hour or an hour and a half. Baron Lenk's gun-cotton lies four, six, or eight weeks in a stream. The French cotton had, after washing, so much free acid left, that wood-ash lye (a solution of carbonate of potash, therefore) was neutralized by contact with it, and after long use became sour. Baron Lenk's cotton is so freed from acid by long immersion, that a two per cent. solution of potash, in which two cwt. of gun-cotton had been boiled, has lost none of its alkaline properties—that is to say, that the cotton was completely free from acids, as experiments wholly accordant with those of the Imperial (Austrian) Engineers' Committee fully demonstrated. The French gun-cotton having been prepared in a manner so different, it must necessarily have had a different composition to that of Baron Lenk's; hence it is clear that the French experimental results cannot, without considerable reserve, be accepted as precedents."

(2) "*Analysis of Austrian Gun-cotton. Laboratory of Engineers' Committee,* 1861.

In 100 parts.	Trinitro-cellulose, calculated.	No. 4.
Carbon	24·3	25·1
Hydrogen	2·3	3·0

University Laboratory, 1863.

In 100 parts.	No. 3. 1856.		No. 6. 1860.		No. 14. 1862.			Dinitro-cellulose, calculated.
	1.	2.	1.	2.	1.	2.	3.	
Carbon	24·4	24·5	24·6	24·2	23·6	23·9	24·1	28·6
Hydrogen	2·7	2·8	2·6	2·7	2·6	2·4	2·4	3·2

"If this analysis differs somewhat from the theoretical formula of the trinitro-cellulose, the circumstance must be remembered that cotton is not pure cellulose, but that it consists of long-extended vegetable cellules, in which there is always a little albuminous substance containing over 50 per cent. carbon, and 7 per cent. hydrogen, the presence of which even in such quantities easily increases the percentage of carbon and hydrogen. The treatment with soluble glass has no influence on Baron Lenk's gun-cotton, it being previously free from acids. Gun-cotton is always put into comparison as an explosive compound with gunpowder; but it must be remembered that one of the component parts of gunpowder (charcoal) is most irregular

in quality, especially where the primitive method of preparing it is followed. Still, in theoretical disquisitions upon gunpowder, charcoal is taken into account as pure carbon."

(3) "In the magazines of gun-cotton at the Neustadter Haide, there are stores of various years. In the laboratory of the University there are samples of Hirtenberg gun-cotton of three several years, which have been examined by the above named artillery officers, and they have been found not to differ materially in their composition from trinitro-cellulose. For instance—

In 100 parts.	Trinitro-cellulose, calculated.	No. 3. 1856.		No. 6. 1860.		No. 14. 1862.		1862.
		1.	2.	1.	2.	1.	2.	3.
Carbon	24·3	24·4	24·5	24·6	24·2	23·6	23·9	24·1
Hydrogen	2·3	2·7	2·8	2·6	2·7	2·6	2·4	2·4

"If these results are compared with each other, there can be no right to say that Hirtenberg gun-cotton alters by keeping. They agree as far with each other as analyses of the same material usually do. It is to be regretted, on this as on many other accounts, that during the last twelve years such analyses were not frequently repeated. If the opponents of gun-cotton, in performing an adverse experiment, heat the substance in a test-tube up to 100° C., and holding litmus-paper over it, deduce from redness of the latter that gun-cotton changes after long keeping, they merely prove thereby that gun-cotton changes at 100° C. Of an explosive compound, it can only be required that *it shall not deteriorate within certain limits of temperature,—a requisition amply fulfilled by Lenk's gun-cotton.*

"Some varieties of gun-cotton, if enclosed together with litmus-paper in a tube, often manifest an acid reaction at ordinary temperature. This may arise from various causes. There may exist, for example, free acids. These acids may be the result of nitrogen partially oxidized, and may result from imperfectly worked cotton. This assumption granted, the phenomenon is explained, and the cause easily avoided. It may arise from decomposition of the gun-cotton, atmospheric dampness having brought about a partial reconstitution of the cellulose."

(4) "But some specimens of Lenk's cotton do not even yield traces of decomposition. A parcel of Hirtenberg cotton was laid for six weeks in a pond, and not subsequently treated with potash. It was then deposited in a running stream, afterwards exposed for one month to the air, being subjected to all the various influences of dew, rain, and sun, day and night continuously. It retains all its original explosive qualities, and fails to redden litmus-paper, even though the latter be wrapped in a mass of this cotton and allowed to remain for many days. The results of an analysis of this cotton were almost identical with the calculated elements of trinitro-cellulose, as the following Table makes apparent:—

	Calculated.	Found.
Carbon	24·2	24·4
Hydrogen	2·3	2·8

(5) "*Temperature at which Gun-cotton ignites.*—The rejection of gun-cotton, in consequence of the changeable nature or explosive quality of the material at low temperatures, is so thoroughly and decidedly contradicted in the Re-

port of Baron von Ebner, that it would be superfluous to go any further into this question—the lowest explosive temperature of the Hirtenberg gun-cotton being therein fixed at 136° C., a temperature which, practically, cannot raise any doubts against the use of gun-cotton."

(6) "*Experimental proofs demonstrate that Lenk's Gun-cotton is not spontaneously combustible.*—The history of gun-cotton, as chronicled by chemists and artillerists, short though the history be, is so full of records of explosion under unexpected circumstances, that an unbiased mind can hardly fail to be impressed with the belief that, amongst the ordinary conditions of military practice, there may be some competent to induce the spontaneous combustion of this material. Nevertheless the experience of Baron Lenk, acquired during a period extending over more than ten years, is more pregnant with reliable testimony than can be found in the entire remaining history of this material.

"*The manufacture of gun-cotton in Hirtenberg consists of a number of perfectly harmless operations*; and it is remarkable that, contrary to what happens with gunpowder, if fire be not actually applied, explosion is impossible. All operations are so arranged that the material acted upon is in a moist or wet condition—hence not explosive. Drying takes place in a capacious building, on every side open to the air. The last process of drying is carried out in the drying-chamber, where it is effected by a stove situated on the outside, distributing its heat to the building by earthenware pipes—drying being thus ensured through a gentle warmth. The gun-cotton next goes either into a magazine to be packed away in chests, or is at once prepared for ammunition. In this magazine, Hirtenberg cotton has been stored for a period of twelve years, and not a single instance of explosion has taken place. How many powder-mills have exploded in that time? In Prussia, however, a drying-chamber has lately blown up. Your Excellency has officially been informed, that in Prussia they have worked for eight years with gun-cotton, and not a single explosion has occurred except the last-named. In the Prussian drying-chamber referred to, a stove with iron smoke-pipe was used—a sufficient explanation of the misfortune.

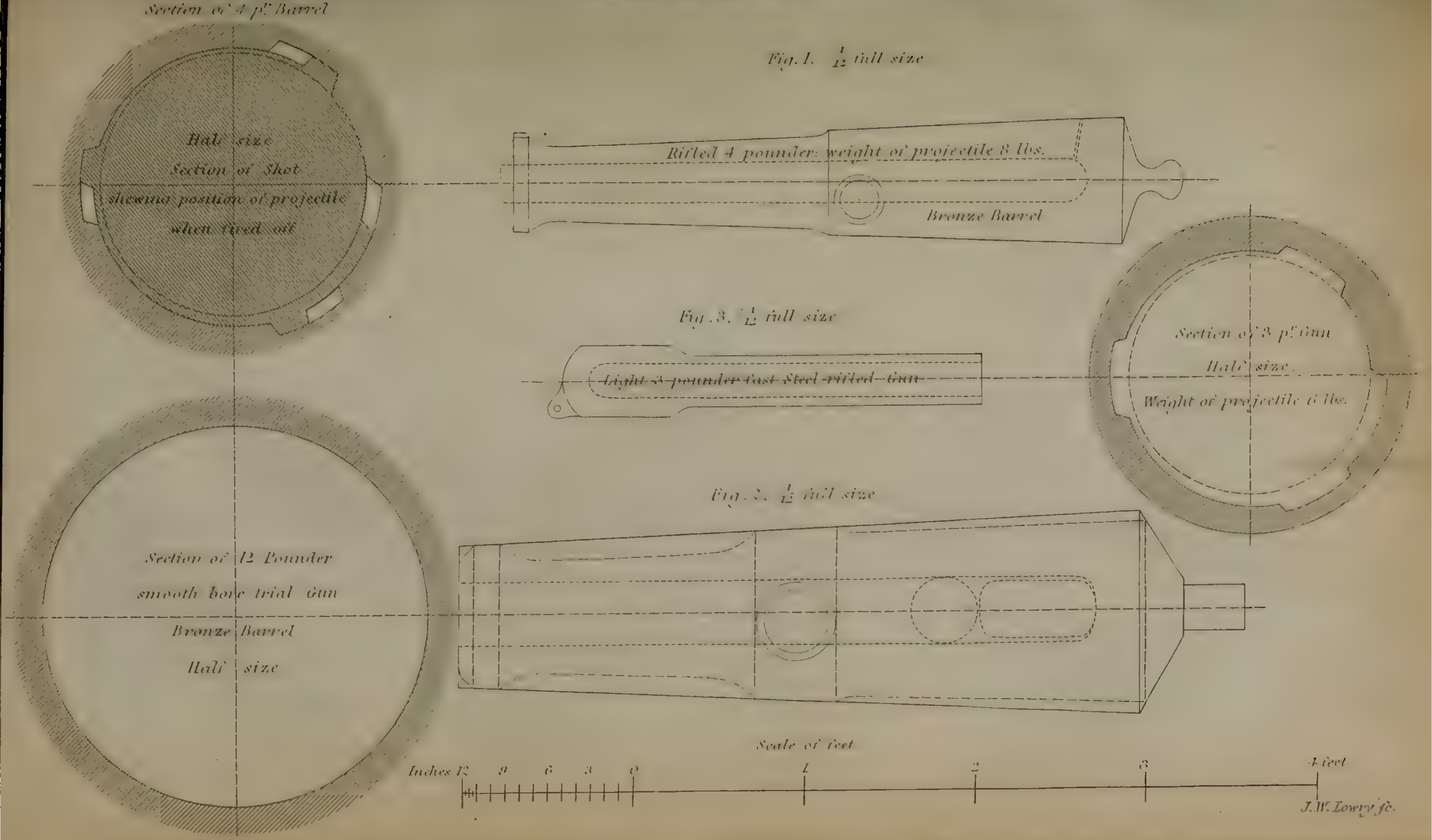
"During twelve years we have prepared gun-cotton at Hirtenberg for ammunition—that is, for yarns, spun ropes, and threads twisted and woven. One single case of explosion has occurred in the course of Baron Lenk's manufacture, the result of improper speed of working the spinning machinery. Now, the circumstance hardly need be insisted on, that gunpowder as well as gun-cotton can be exploded by friction. Gun-cotton has been used for military purposes now more than twelve years; it has also been employed for mining and blasting. It has been subjected to every variety of transport. Packed in black wooden chests, it has been exposed to sunshine for months together—all this without one single accident. In the face of such testimony, it cannot be said that gun-cotton manifests any tendency to explode spontaneously."

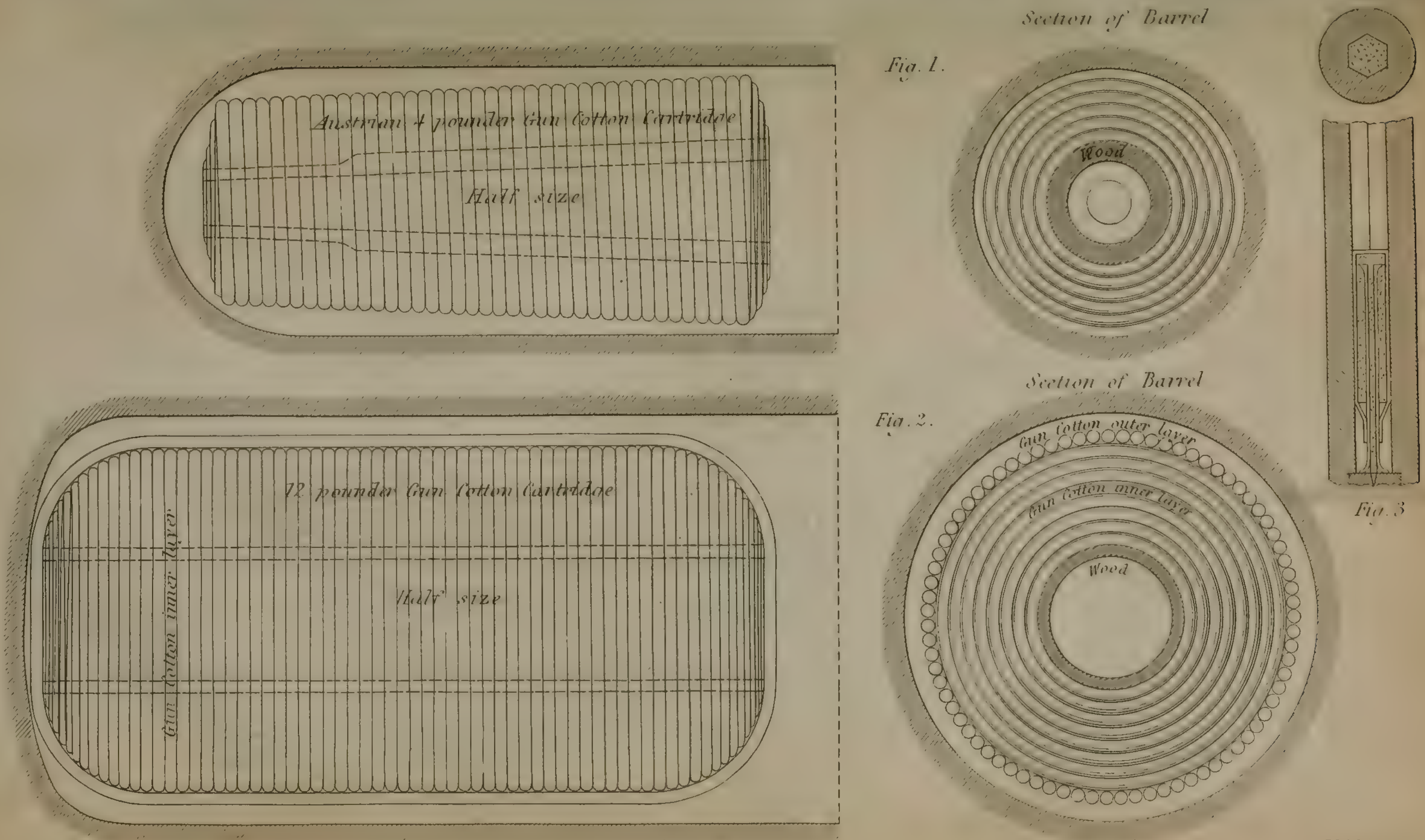
(7) "Lieutenant von Karolyi's analysis of the gases of combustion of Lenk's gun-cotton, which he made in the Chemical Laboratory of the Engineers' Corps Committee, may be seen in the 'Report of the Imperial Academy of Science,' vol. xlvii. Mathematical and Physical Part, p. 59, and is given in the following Table, in which the gases of combustion of powder according to Bunsen (*vide* Poggendorff, 4th series, vol. xii. p. 131) are cited in comparison with those of gun-cotton.

Gases of Combustion. Volume per cent.		Bunsen.	Karolyi.			
		Sporting powder.	Rifle powder.	Ordnance powder.	Gun-cotton.	
Nitrogen	N....	41·1	35·3	37·6		12·7
Carbonic acid	CO_2...	52·7	48·9	42·7		20·8
Carbonic oxide	CO...	3·9	5·2	10·2		29·0
Hydrogen	H.....	1·2	6·9	5·9		3·2
Sulphuretted hydrogen	HS...	0·6	0·67	0·86	Carbon	1·8
Oxygen	O.....	0·52	—	—	Water	25·37
Light carburetted hydrogen	..	—	3·02	2·7		7·2

"If we compare the gases of gunpowder with those of gun-cotton, we easily see that the chemical action of the product of combustion of gun-cotton on the sides of the barrel, if there exists any action at all, must be smaller than with the use of gunpowder, because they are less oxidizing gases than those of gunpowder. Should, therefore, bronze barrels be "burnt out" by the use of gun-cotton, cast steel may be then used instead of bronze, which, in fact, has been successfully done. Moreover bronze gun-barrels have withstood a sufficient number of rounds by using an adequate charge of gun-cotton with elongated cartridges. In this way no alteration of the bore prejudicial to the correctness of aim has taken place. From the steel barrel of a rifle, forty rounds have been fired with gun-cotton cartridges, which have hit the target 300 yards distant in an unexceptionable manner. After the said number of rounds, the barrel was internally as clean and polished as a mirror. It appears, then, that this problem is solved in a general and satisfactory manner."

(8) "*Application of Gun-cotton to Mining Warfare.*—Gun-cotton is also used for mining-purposes and mining warfare. On this subject nothing but what is favourable has been reported by the Imperial Engineers (*vide* Communications of the R. I. Engineers' Committee, 1861, vol. i., by Moritz Baron von Ebner, Colonel of the Engineers). However, it is said that the gases of gun-cotton were more poisonous in mines than those of gunpowder, and therefore the use of gun-cotton for mining warfare is not to be recommended. If we compare the result of Lieutenant Karolyi's analysis of the combustion-gases of gun-cotton with those of gunpowder as above given, we observe that both of them contain irrespirable gases; further, that they contain qualitatively the same sort of irrespirable gases; and although the relative quantities of some of the gases from powder and gun-cotton are different, the effect of those gases leads to the same practical result, viz. that, after blowing up a mine, one cannot without danger approach the spot of the explosion before renewing the air by ventilation. In this respect, we may say that the gases of gun-cotton will be more quickly removed by ventilation than those of gunpowder, because the first-named contain a greater quantity of gases easily dissipated, since 100 pounds of gunpowder contains 68 pounds of fixed solid matter, which alone suffices to make respiration almost impossible. It is not probable that an explosive compound will be found which will produce any other but irrespirable gases. It is one and the same in practice, whether a cellar contains 40 per cent. of carbonic acid and 10 per cent. carbonic oxide, or 30 per cent. carbonic oxide and 20 per cent. carbonic acid, inasmuch as no one could, without danger of suffocation, enter such a cellar. Both the gases of gun-cotton and of gunpowder, according to Karolyi, may be ignited by a match."


Section of 4 pr. Barrel
Half size
Section of Shot
shewing position of projectile
when fired off
Fig. 1. 1/12 full size
Rifled 4 pounder: weight of projectile 8 lbs.
Bronze Barrel
Fig. 3. 1/12 full size
Light 3 pounder Cast Steel rifled Gun
Section of 3 pr. Gun
Half size.
Weight of projectile 6 lbs.
Section of 12 Pounder
smooth bore trial Gun
Bronze Barrel
Half size
Fig. 2. 1/12 full size
Scale of feet
Inches 12 9 6 3 0 1 2 3 4 feet
J.W. Lowry fc.


Austrian 4 pounder Gun Cotton Cartridge
Half size
12 pounder Gun Cotton Cartridge
Half size
Gun Cotton inner layer
Fig. 1.
Section of Barrel
Wood
Fig. 2.
Section of Barrel
Gun Cotton outer layer
Gun Cotton inner layer
Wood
Fig. 3

J.W. Lowry sc.

Apparatus used in the manufacture of gun cotton.

Fig. 1.

$\frac{1}{30}$ Full Size

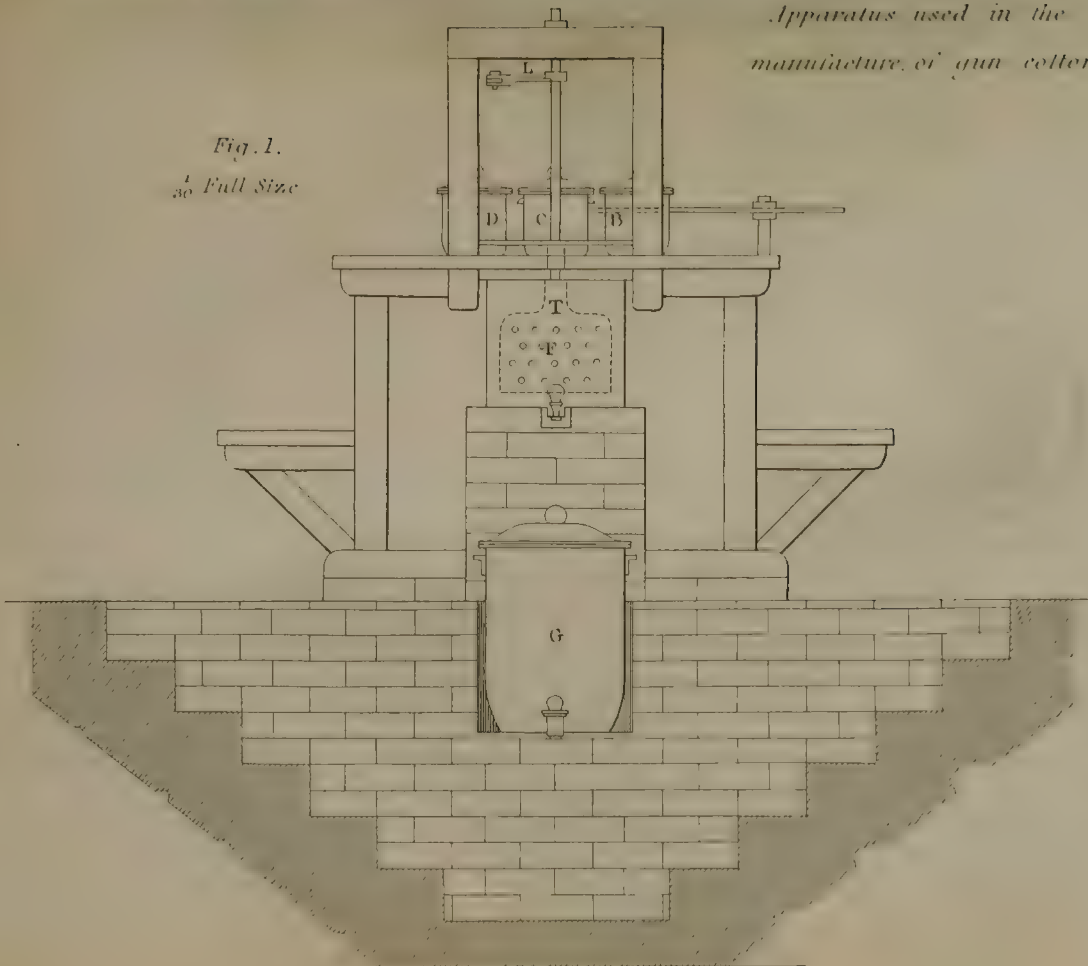


Fig. 2.
Longitudinal Section

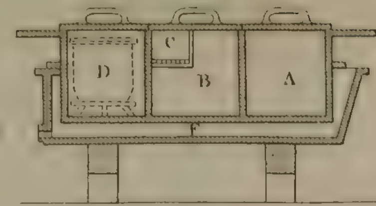


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Fig. 2a.
End Section

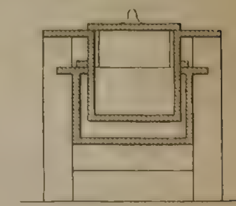
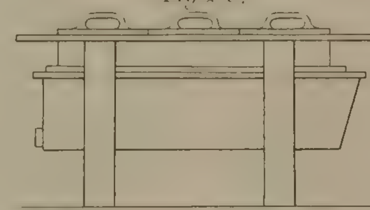


Fig 2 b.



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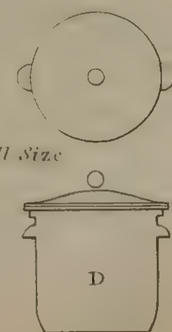

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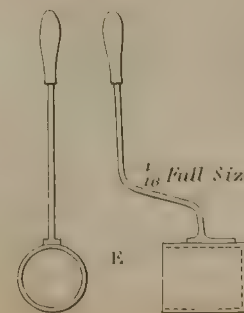

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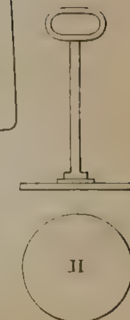
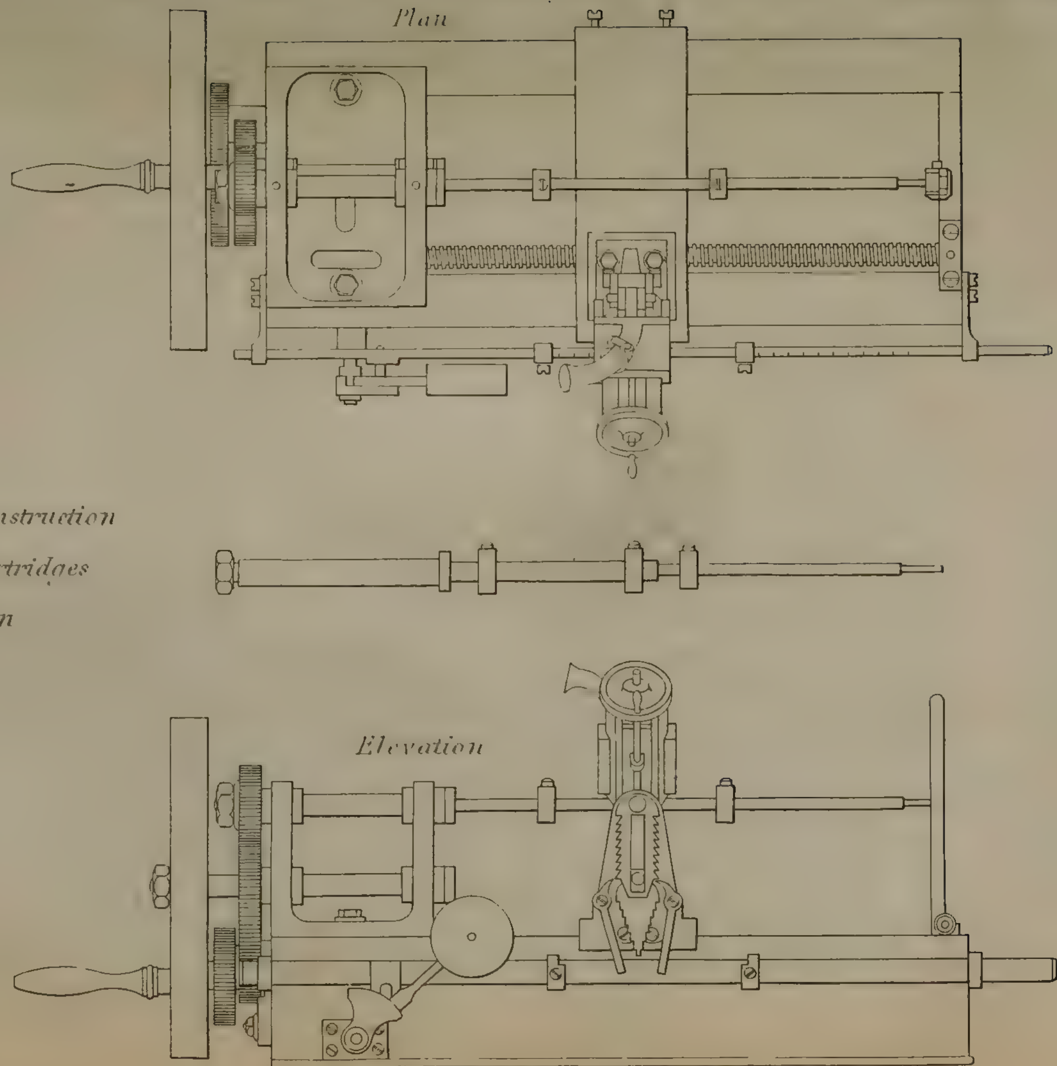


J. W. Lowry, fc.



Machine for the construction of Gun Cotton Cartridges for Cannon

J.W. Lowry fc.

Report on the Chemical Nature of Alloys. By A. Matthiessen, *F.R.S., Lecturer on Chemistry in St. Mary's Hospital.*

Our knowledge of this subject is at present very limited; and, as far as we can ascertain, a liquid alloy of two metals may be either

1. A solution of one metal in another, or
2. A chemical combination, or
3. A mechanical mixture, or
4. A solution or mixture of two or all of the above.

On the contrary, an alloy in the solid state may be either

1. A solidified solution of one metal in the other, or
2. A chemical combination, or
3. A mechanical mixture, or
4. A solidified solution or mechanical mixture of two or all of the above.

Under the term solution of one metal in another, I understand one like that of ether and alcohol; for these two liquids may be mixed in any proportion, and they will not separate, by standing, into two layers. Oil and water, on the contrary, when shaken up well together, present for a moment a homogeneous mass, and as such may be considered a mechanical mixture of the two. The case of mixing ether and water together is somewhat different; for ether dissolves a certain amount of water, and water a certain amount of ether: when these liquids, say in equal parts, are shaken well together, then, as with oil and water, for a time a homogeneous mass will exist; such a one, however, is not a mechanical mixture of ether and water, but a mechanical mixture of a solution of ether in water and of water in ether. Again, when sulphuric acid is added to a large quantity of water, the solution is not a simple one of sulphuric acid in water, but a solution of a chemical combination of sulphuric acid and water in water.

Under the term solidified solution, I understand a most intimate mixture, such as would occur in the sudden conversion of a solution into a solid, and a much more intimate mixture than can be obtained by ordinary mechanical means—in fact a perfectly homogeneous diffusion of one body in another. An excellent example of a homogeneous diffusion is furnished by glass, which is formed in the liquid state at a high temperature, and solidifies on cooling without separation of the different silicates. But how are we to find out what an alloy is? Chemistry only affords us means (*by analysis*) by which we are enabled to determine whether an alloy is a homogeneous mass or not, thereby indicating the presence or absence of mechanical mixtures.

This is not enough for us to determine the chemical nature of alloys; we must therefore look elsewhere and see whether we cannot gain information on the subject; and in doing so we shall find that the study of their physical properties offers a means whereby the chemical nature of an alloy may be ascertained.

The physical properties may be divided into two classes—

I. Those which do not indicate the chemical nature of the alloy.
II. Those which do indicate the chemical nature of the alloy.

To the first belong, for instance—

1. *Specific Gravity.*—On comparing those observed with those calculated, very little difference will be found between the values; take as example those of the bismuth-lead alloys, and those of the metals tin and gold*.

* Phil. Trans. 1860, p. 177.

Bismuth-lead Series.

Alloy.	Mean of		Calculated specific gravity, from volume.
	Specific gravity found	T.	
Bi_{30} Pb	9·844	21°·7	9·845
Bi_{24} Pb	9·845	21·6	9·850
Bi_{20} Pb	9·850	21·3	9·856
Bi_{12} Pb	9·887	20·6	9·877
Bi_{10} Pb	9·893	19·5	9·887
Bi_{8} Pb	9·934	21·1	9·902
Bi_{6} Pb	9·973	15·0	9·927
Bi_{4} Pb	10·048	10·7	9·974
Bi_{2} Pb	10·235	12·5	10·098
Bi Pb	10·538	14·0	10·290
Bi Pb_{2}	10·956	14·9	10·541
Bi Pb_{4}	11·141	12·7	10·805
Bi Pb_{6}	11·161	14·8	10·942
Bi Pb_{8}	11·188	20·8	11·026
Bi Pb_{10}	11·196	20·2	11·083
Bi Pb_{24}	11·280	22·5	11·238
Bi Pb_{100}	11·331	23·0	11·340

Tin-gold Series.

Alloy.	Mean of		Calculated specific gravity, from volume.
	Specific gravity found.	T.	
Sn_{100} Au	7·441	22°·9	7·446
Sn_{30} Au	7·801	22·8	7·786
Sn_{18} Au	8·118	22·4	8·092
Sn_{12} Au	8·470	23·1	8·452
Sn_{8} Au	8·931	25·6	8·951
Sn_{6} Au	9·405	23·7	9·407
Sn_{5} Au	9·715	22·4	9·743
Sn_{4} Au	10·168	23·7	10·206
Sn_{3} Au	10·794	23·6	10·885
Sn_{2} Au	11·833	14·6	11·978
Sn Au	14·244	14·2	14·028
Sn Au_{2}	16·367	15·4	15·913

Now I do not think it possible from such small differences as the above to deduce anything definite respecting the chemical nature of the alloys; still, as we shall see, they help in some cases to confirm deductions from other properties.

2. *Crystalline Form.*—When zinc and antimony are fused together in

different proportions* and allowed to crystallize, the alloys containing from 20–33 per cent. zinc crystallize in silver-white rhombic crystals, P : P (P : P at the terminal edges 118° 24′ and 95° 24′, at the lateral edges 115° 30′), and those containing from 43–70 per cent. zinc in rhombic prisms of 117° 63′ truncated at the edges. Further, it has been shown that the alloys of tin and gold containing from 25–43·5 per cent. gold crystallize all in the same form†. This is therefore an important point to bear in mind, for it follows that alloys of a definite crystalline form are not necessarily chemical combinations.

3. *Points of Fusion.*—It is a matter of common observation that the fusing-point of a mixture is lower than the mean fusing-point of the constituents. The fluxes so well known in metallurgy exemplify this, as also do the alloys, as well as mixtures of the solid fatty acids. There is I believe no case known where the fusing-point of a mixture is higher than the mean fusing-point of the components.

This fact admits of explanation as follows:—

It is generally admitted that matter in a solid state exhibits excess of attraction over repulsion, whilst in the liquid state these forces are balanced, and in the gaseous state repulsion predominates over attraction. Let us assume that similar particles of matter attract each other more powerfully than dissimilar ones attract each other. It will then follow that the attraction subsisting between the particles of a mixture will be sooner overcome by repulsion than will the attraction in the case of a homogeneous body; hence mixtures should fuse more readily than their constituents.

To the second class of properties belong

Conducting-Powers for Heat and Electricity.—According to some experimenters the values obtained for the conducting-power of the metals‡ and alloys§ for heat and electricity are the same; so that, if either of these properties be determined for a series of alloys, we shall then be able to deduce their chemical nature: but before going into this subject more widely let me say a word respecting the other physical properties. To which of the two classes many belong it is at present impossible to say; for the results obtained by different observers vary so much, and in most cases only a very few alloys have been experimented with. There is, however, no doubt that the determination of some of the other physical properties would materially aid us in ascertaining the chemical nature of the alloys; but in order to obtain such results as will aid us in the inquiry, it is absolutely necessary to employ only purified metals. I do not say chemically pure; for no chemist would give much credit to anyone stating that he had prepared 5 to 10 kilogrammes of any metals in a state of chemical purity, such being the quantities required to carry out one such research. The only manner to proceed in such cases is to satisfy oneself, by repeatedly purifying and by using metals of different preparations by different methods, that the amount of impurity remaining with the metal has no influence on the results obtained. For of what use is a research into the physical properties of the metals and their alloys made with impure metals, when we know that traces of impurity materially affect and alter them?

I will now proceed to show how we may deduce the chemical nature

* J. P. Cooke, Journ. Amer. Acad., New Series, vol. v. p. 337.
† Matthiessen and v. Bose, Proc. Royal Soc. (1861) vol. xi. p. 433.
‡ Wiedemann and Franz, Pogg. Ann. vol. lxxxix. p. 497.
§ Wiedemann, Pogg. Ann. vol. cviii. p. 393.

of alloys in a solid state, from the determination of their conducting-powers for electricity*.

The number of alloys experimented with was upwards of 250; they were all made of purified metals, and their conducting-power determined with a modification of Wheatstone's balance, arranged by Kirchhoff, under whose direction the first results were obtained†. The method of observation emanating from such a distinguished physicist is a sufficient proof of its accuracy and trustworthiness. And here a great difficulty in carrying out such researches may be mentioned; for one is apt to fall into one of two errors: either the metals used for the experiments are not pure, or the method employed for the determinations is faulty. Thus, for instance, compare the experiments on the influence of temperature on the electric conducting-power of the metals between 0° and 100°. Calling the conducting-power of each at 0° 100, at 100° it is, according to

	Conducting-power at 0°	Conducting-power at 100° Lenz ‡.	Arndtsen §.	Becquerel ‖.	Matthiessen & v. Bose ¶.
Silver	100	74·5	74·5	71·3	71·6
Copper	100	77·7	71·7	70·8	70·3
Gold	100	84·9	....	74·6	71·7
Zinc	100	....	....	73·1	71·2
Cadmium ..	100	....	....	71·2	70·7
Iron	100	....	68·3	67·9	61·2**
Tin	100	71·8	....	61·8	70·1
Platinum ..	100	....	75·4	84·3	
Lead	100	71·4	72·6	69·7	70·4
Antimony ..	100	....	....	....	70·5
Arsenic	100	....	....	....	69·9
Bismuth ..	100	....	....	....	70·7

Now Lenz and Arndtsen experimented with commercially pure metals. Arndtsen remarks at the end of his paper, "From the foregoing data it is very probable that the influence of temperature on the conducting-power of all metals in the state of absolute purity would be found to be in all cases the same." Becquerel, on the contrary, used pure metals for his experiments, but his method of observation was very indifferent. The results given in the last column were obtained by the employment of Kirchhoff's arrangement of Wheatstone's balance, as well as pure metals. On looking at the above, it is obvious that from the last series we may deduce the law that the conducting-power of pure metals (iron excepted) decreases between 0° and 100° in the same degree; whereas from the others the existence of the law is only problematical.

The conclusions drawn from the research on the electric conducting-power of alloys were as follows:—

That in respect to this property the metals may be divided into two classes.

A. Those metals (lead, tin, zinc, and cadmium) which when alloyed with each other conduct electricity in the ratio of their relative volumes.

B. Those metals (bismuth, antimony, platinum, palladium, iron, aluminium, gold, copper, silver, and probably most of the other metals) which when

* Phil. Trans. 1860. † Phil. Mag. Dec. 1859.
‡ Pogg. Ann. vol. xxxiv. p. 418, and vol. xlv. p. 105. § Pogg. Ann. vol. civ. p. 1.
‖ Ann. de Chim. et de Phys. (3) vol. xvii. p. 242.
¶ Phil. Trans. 1862, p. 1. ** Proc. Royal Soc. vol. xii. p. 472.

alloyed with one another, or with one of those belonging to Class A, do not conduct electricity in the ratio of their relative volumes, but always in a lower degree than that calculated from the mean of their volumes. In the above statement I have assumed the theoretical conducting-power of an alloy equal to that of the components, under the supposition that each of them is a separate wire, lying side by side, and soldered together at the ends.

If we now look at the curves representing the conducting-power of the different series of alloys, we shall find that (see Plate V.)—

I. Those belonging to the alloys made of the metals of Class A with one another are almost straight lines. As type the lead-tin curve is given.

II. The curves of those made of the metals of Class A with those of Class B show a rapid decrement on the side beginning with the metal belonging to Class B, and then turning and going in a straight line to the other side, namely to the Class A metal. As type the tin-copper curve is given.

III. The curves of those made of the metals of Class B with one another show a rapid decrement on both sides of the curve, and the turning-points connected with each other by nearly straight lines. As type the gold-silver curve is given.

The curves, then, representing the conducting-powers of the alloys having, according to the class of metals of which they are made, almost always the same form, we may, if we know to which class the metals composing them belong, draw a curve which will approximately represent the conducting-power of a series of alloys. Of the exceptions to this rule I shall presently speak.

Let us now examine the first group of alloys, and see what grounds there are for supposing that the solid alloys belonging to it are only solidified solutions of the one metal in the other. In order to do this, I shall show that they are neither mechanical mixtures (with exception of the lead-zinc alloys) nor chemical combinations.

First. If they were mechanical mixtures, the metals composing them, if their specific gravities were not the same, would separate into two layers when fused and cooled slowly, as in the cases of the lead-zinc alloys*; for when these two metals (say equal parts) are fused together and allowed to cool slowly, they separate into two layers, the upper one (zinc) containing 1·2 per cent. lead, and the lower one (lead) with 1·6 per cent. zinc. Now if, instead of cooling the mixture slowly, it had been cooled rapidly, such an alloy might be regarded as a mechanical mixture of a solidified solution of lead in zinc and zinc in lead, or if well mixed in a liquid state, such a mixture would be analogous to one of ether and water when shaken up well together, and not as one of lead and zinc analogous to oil and water.

A true mechanical mixture of two metals, either in the liquid or solid state, is I believe not known.

That the alloys of lead and tin, for instance, are not mechanical mixtures, is proved by their not separating into two layers on being slowly cooled after fusion; for, if they were, they would behave like lead and zinc, as tin and zinc have nearly the same specific gravities, that of tin being 7·293 and that of zinc 7·148.

2ndly. If these alloys were mechanical mixtures of the metals composing them, we should not be able to press homogeneous wires; now it has been proved that wires of the same alloy have the same conducting-power, whether tested at the end coming first or last out of the press, or whether pressed at different times.

* Matthiessen and v. Bose, Proc. Royal Soc. vol. xi. p. 430.

That these alloys in the solid state are not chemical combinations is indicated, First, by their having the theoretical conducting-power, as well as the theoretical percentage decrement* in their conducting-power between 0° and 100° C.; for the following law has been found to hold good for all alloys of the first and third groups, as well as for a part of those belonging to the second: *The observed percentage decrement in the conducting-power of an alloy between* 0° *and* 100° C. *is to that calculated between* 0° *and* 100° C. *as the observed conducting-power at* 100° C. *is to that calculated at* 100° C. Secondly. It may be urged that the solidifying point not always being the same as the point of fusion (for instance, in the lead-tin alloys), and the existence of the so-called stationary points, is a sign of chemical combination. They certainly do point to the probable existence of chemical combinations in the liquid alloy, but not in the solid. That chemical combinations may exist at high temperatures in a fused mass, which suffer decomposition on cooling or solidifying, becomes very probable from the following experiment:—When iron and excess of iodine are heated together in a stout glass tube, the iodine combines with the iron to form a compound, which decomposes with evolution of iodine on being cooled, the protiodide of iron remaining behind†. Wanklyn and Carius, who made the above observation, suppose that at the high temperature the periodide of iron is formed, and that, on cooling, this salt splits up into the protiodide of iron and free iodine. May we not assume that what has been shown to occur with iodine may also occur with other elements —oxygen, for instance, it forming with some bodies at high temperatures oxides which suffer decomposition with evolution of oxygen at lower ones. This would then give us the explanation of the spitting of silver. Supposing, therefore, that chemical combinations can exist at high temperatures which suffer decomposition on cooling, we can then understand why some alloys fuse at one temperature and solidify at a lower one: for example, the tin-lead alloys, according to Pillichody‡,

	Sn_4Pb.	Sn_3Pb.	Sn_2Pb.	$SnPb$.	$SnPb_2$.	$SnPb_3$.	$SnPb_4$.
Fuse....	187°	181°	197°	235°	270°	283°	292°
Solidify..	181	181	181	181	181	181	181

who makes the following remarks on them:—"When the points of solidification are observed by immersing the thermometer in the melted alloy, it usually exhibits, during the passage of the mass from the liquid to the solid state, two stationary points. This effect is due to the separation of one or other of the component metals, while an alloy of constant composition still remains liquid. This alloy has the composition of Sn_3Pb. An alloy richer in lead would first deposit lead, and an alloy containing a larger proportion of tin would first deposit tin,—the alloy Sn_3Pb remaining liquid for a longer or shorter time, and ultimately solidifying at 181°. This temperature therefore corresponds to the lowest melting-point that can be exhibited by an alloy of tin and lead, a larger proportion of either metal causing the melting-point to rise."

These low fusing-points are no proof of the existence of chemical combinations in the solid alloy, but admit of explanation by assuming that chemical attraction between the two metals comes into play as soon as the temperature rises, and the moment the smallest portions melt, then the actual chemical compound is formed which fuses at the low temperature, and then acts as a

* Matthiessen and Vogt, Proceedings of the Royal Society, vol. xii. p. 652.

† Liebig's Ann. vol. cxx. p. 69. ‡ Journ. Chem. Soc. vol. xv. p. 30.

solvent for the particles of metal next to it, and so promotes the combination of the metals where this can take place. When the alloy $Sn\,Pb_4$, for instance, solidifies, it must not be strictly regarded as a homogeneous diffusion of tin and lead in one another, if Pillichody's statement be correct (although it will not be far from it, as all the tin-lead alloys have the theoretical conducting-power), but rather as a homogeneous diffusion of tin and lead in one another from the formation of the alloy $Sn_3\,Pb$, with the excess of lead mechanically diffused through the mass, as this, according to him, separates out before the alloy $Sn_3\,Pb$ solidifies.

With respect to the chemical nature of these and other alloys in a liquid state little is known; it is, however, very necessary to draw a line between the solid and the liquid alloy, when speaking of their chemical constitution. No doubt the determination of the electric conducting-power of the liquid will throw much light on their chemical nature. The investigation of those where the so-called stationary points have been observed, and where the melting and solidifying points do not coincide, will be especially interesting. As yet, I believe, no such observations have been made.

Passing on now to the alloys of the second group, the question for consideration will naturally be, what is the cause of the rapid decrement in the conducting-power of Class B metals when alloyed with traces of one of the Class A metals (in the solid alloy)?

That it is not due to the formation of chemical combinations, is proved by the following:—

I. At the turning-points of the curves representing the conducting-power of this group of alloys they contain only very small percentages of the Class A metal. Thus, at those of the alloys

	Percentage of	
Bismuth-tin	tin	0·6
Bismuth-lead	lead	2·0
Silver-tin	tin	2·6

II. The great similarity of the curves of this group speaks greatly against the existence of chemical combinations in the solid alloy. The curves of the following series show this in a very marked degree:—the bismuth-lead, bismuth-tin, copper-tin, copper-zinc, silver-lead, silver-tin.

III. On examination of that part of the curve where the rapid decrement takes place, we find that it requires about twice as much lead as of tin to reduce the conducting-power of the Class B metal to the same extent: thus, to reduce that of silver to 67, it would require 0·9 vol. per cent. of lead, or 0·7 per cent. of tin; and to reduce it to 47·6, 1·4 vol. per cent. lead, or 0·7 per cent. tin. Again, to reduce bismuth to 0·261, it would require 0·4 vol. per cent. lead, or 0·62 per cent. tin; and to reduce it to 0·255 with lead, or to 0·245 with tin, it requires 1·76 vol. per cent. lead, or 0·85 per cent. tin *.

From these facts we can hardly assume that the rapid decrement in the curve of the Class B metal is due to the existence of chemical combination. The reason of this great decrement in the conducting-power might be looked for in the process of solidification, for it is well known what a great effect traces of foreign metals have on the crystalline structure of some metals. Cooke has, I think, stated that absolutely pure antimony crystallizes with great difficulty,—an observation which I can corroborate; for, when trying to obtain crystals of that metal for thermo-electric experiments, I found that the purer the antimony the smaller the crystals, in fact I could not obtain any for my purpose.

* Phil. Trans. 1860, p. 171.

Again, Mr. W. Baker (of Sheffield) informs me that just the converse takes place with lead; for the purer the lead the larger the crystals. Now, these facts being known, it seemed possible that in alloying some metals with traces of others, either the crystalline form of the alloy might be altered or the tendency to crystallize increased or decreased, and thus cause the great change in the conducting-power. This supposition is, however, proved wrong by the following experiments*:—

I. If to melted tin traces of lead or bismuth be added, a decrement in the conducting-power is observed which increases with each successive addition of metal.

II. If to melted lead traces of tin be added, an increment in the conducting-power is observed; if, on the contrary, bismuth be added, a decrement.

III. If to melted bismuth traces of tin or lead be added, a decrement; but on further addition, an increment in the conducting-power will be observed. This behaviour corresponds with that of these metals in the solid state; in fact, if the conducting-powers of a series of these alloys in a liquid state were determined, the curve representing them would in all probability be similar to that of the alloys in a solid state.

The explanation which I would offer of the cause of this behaviour is as follows:—

Let it be assumed that the metals belonging to Class B, when they are alloyed either with one another or with one of Class A, undergo a change (in other words, are converted into an allotropic modification), and that this change is brought about by a small quantity of the other metal, the quantity of the metal required to complete the conversion being dependent on the metal employed. With the help of this hypothesis, we are able to explain many of the phenomena which occur when making the alloys, as well as the reason of the marked change in most of the physical properties of some metals when alloyed with traces of another.

A few examples will show this clearly. Take, for instance, the case of the zinc-copper alloys, the curve representing the conducting-power of these alloys has the same form as those of the other alloys belonging to this group, and the percentage decrement in their conducting-power between 0° and 100° is exactly that which would have been deduced from the law which regulates this property. From these results it may be deduced that solid alloys of zinc and copper are only solidified solutions of zinc and of an allotropic modification of copper in one another.

Some experimenters have expressed their opinion that there exist chemical compounds in these alloys; and they base their supposition on the following facts:—

I. When zinc is added to copper in the melted state, a great evolution of heat is observed.

II. That some of the zinc-copper alloys crystallize more readily than others.

Storer, in his paper† "On the Copper-zinc Alloys," states, "It is a well-known fact that the combination of copper with zinc is attended with ebullition of considerable violence, so that portions of the melted mass are often thrown to a distance of several feet from the crucible. Yet it does not appear to have been previously noticed by chemists that this action is much more energetic while the first portions of zinc are being added to the copper, and that the loss of zinc by volatilization is far greater at this time than at any subsequent stage of the operation." This fact may be explained by assuming that the specific heat of the allotropic modification of copper is less than that of copper in its

* Matthiessen and Vogt, Phil. Mag., March 1862.

† Memoirs of the American Academy, vol. viii. p. 26.

ordinary state; hence the great evolution on the addition of the first portions of zinc to the melted copper, for it only requires a small quantity of zinc to convert copper into its allotropic modification. Person has already proved that heat is evolved when melted lead is added to melted bismuth, and he explains it by assuming that the specific heat of the alloy is less than that of the component metals. The great evolution of heat might possibly be an indication of the existence of chemical compounds in the liquid alloy; but of this we have at present no data upon which we can go, as very little is known as to the behaviour of these alloys in a liquid state.

Storer in the same paper* states, "Upon the assumption that the crystals of the alloys of copper and zinc belong to the regular system, as well as upon the fact that none of the crystals have been found to contain any larger quantity of the component metals than was contained in the remainder of the molten liquid from which they were separated, I have based my conclusion that the alloys of copper and zinc are isomorphous mixtures of the two metals; on this hypothesis it is of course presumed that both copper and zinc are capable of crystallizing in the regular system." And, further on, "Indeed these fibres, although described by Calvert and Johnson as prismatic crystals indicating that the alloy Cu Sn is a definite chemical compound, are evidently nothing more than a collection of octahedral crystals, similar to those which form the fibres of sublimed sal-ammoniac and of several metals."

This answer, respecting the existence of chemical compounds in these alloys, is sufficient to prove their non-existence, more especially when it has been shown, which I have already pointed out in this Report, that alloys of a definite crystalline form are not necessarily chemical compounds.

Storer, as will be seen from the above, has arrived at nearly the same conclusions with regard to the chemical nature of these alloys as I have done, the main difference being that he has not taken into consideration the marked change in most of the physical properties of copper when it is alloyed with traces of zinc.

It has been shown that the action of reagents on these alloys is different to their action on the two metals in contact with one another, and that this is an indication of the existence of chemical compounds. By the above hypothesis, this behaviour may be explained by assuming that the action of reagents on the allotropic modification of copper is not the same as their action on ordinary copper; when, therefore, we try the action of different reagents on alloys, we cannot expect to find the same results as when experimenting on the metals unalloyed in contact with one another. Another reason for the different action of reagents on alloys and on the metals in contact with one another is, that in every case one metal is attacked more easily than the other, so that after a certain time the mass of the alloy becomes covered with a coating of the more difficultly soluble metal, whereby it is protected from the further action of the reagent (gold-assaying).

What was said of the lead-zinc alloys may also apply to those of bismuth-zinc; for when these metals are fused together, they do not mix with each other, but separate into two layers, the upper one (zinc) containing 2·4 per cent. bismuth, and the lower one (bismuth) with from 9 to 14 per cent. zinc. Here then, again, we have another example of mechanical mixture; for if these metals were mixed together in a liquid state, such a mixture would be one of a solution of the allotropic modification of bismuth in zinc, and one of zinc in the allotropic modification of bismuth; or if the mixture were cooled rapidly, it would be a mechanical mixture of a solidified solution of the allotropic

* Memoirs of the American Academy, vol. viii. p. 29.

modification of bismuth in zinc, and of zinc in the allotropic modification of bismuth.

The above hypothesis explains also why bismuth, when alloyed in the liquid state, with traces of lead or tin shows a decrement, but on further addition an increment in the conducting-power; for it may be assumed that the metals of Class B, when alloyed in the liquid state with traces of another, are also converted into an allotropic modification. This is an important deduction; for it shows that the hypothesis will hold good, not only for alloys in a solid, but also for alloys in a liquid state. Passing on to another series of alloys belonging to this group—namely, the tin-gold series,—it will be seen that the curve representing the conducting-power of these alloys has not the typical form of this group. If it be examined, it will be found that the causes of the irregularities are chemical combinations. Beginning at the tin side of it, we find a slow decrement in the conducting-power to the alloy $Sn_5\,Au$, then a gradual increment to $Sn_2\,Au$, and from this point a slow decrement to $Sn\,Au_2$. Owing to the brittleness and infusibility of the alloys between $Sn\,Au_2$ and that containing 2·7 per cent. tin, no alloy within these limits could be pressed or drawn into wire. From the alloy containing 2·7 per cent. tin to pure gold, the curve becomes a straight line.

That the alloys at these turning-points may be regarded as chemical combinations, is proved by the following facts (see Plate V.):—

I. That these points represent alloys of definite chemical composition.

II. That they represent alloys containing large percentages of each metal, $Sn_5\,Au$ containing 60 per cent., $Sn_2\,Au$ 37 per cent., and $Sn\,Au_2$ 13 per cent. tin.

III. That the specific gravity of the alloy $Sn_5\,Au$ is almost equal to that calculated, whereas $Sn_2\,Au$ expands, and $Sn\,Au_2$ contracts more than any of the other tin-gold alloys experimented with.

IV. That the percentage decrement in conducting-power of these alloys between 0° and 100° does not follow the before-mentioned law.

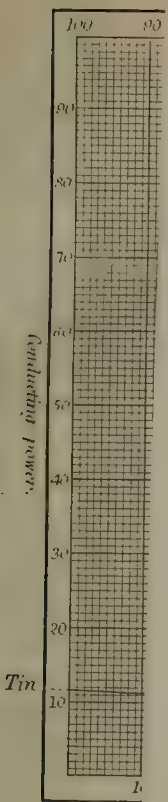
V. That tin and gold dissolve in one another with great readiness; for if to melted tin gold be added, it dissolves in the tin immediately, and evolves so much heat that it is necessary not to add too much at once for fear of losing the contents of the crucible. Copper, on the contrary, placed in melted tin, takes a long time to dissolve in it. Assuming that some of the solid gold-tin alloys are chemical compounds, we then have examples of solid alloys which are solidified solutions of a metal (tin) and a chemical compound ($Sn_5\,Au$) in one another, represented by the part of the curve between pure tin and $Sn_5\,Au$—or solidified solutions of two chemical combinations in one another ($Sn_5\,Au$ and $Sn_2\,Au$), represented by that part of the curve between $Sn_5\,Au$ and $Sn_2\,Au$, and between $Sn_2\,Au$ and $Sn\,Au_2$.

After what has been already stated, the third group of alloys will require very little to be said with regard to their chemical nature; it is only necessary to point out that most of them are only solidified solutions of the allotropic modifications of the metals in one another. The curves representing the conducting-power of the different series of alloys all have the typical form; and the conducting-power decreases between 0° and 100° according to the theoretical amount.

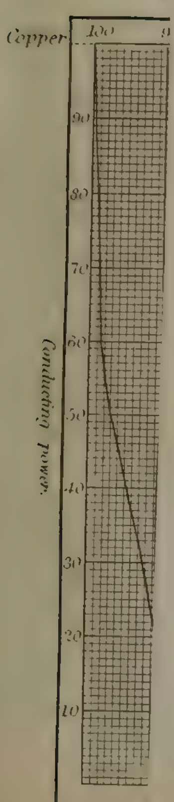
The alloys of copper-silver, however, form an exception; for some of these alloys may be regarded as mechanical mixtures. According to Levol, when silver and copper are fused and well stirred together*, if allowed to cool

* Journ. de Pharm. vol. xvii. p. 111.

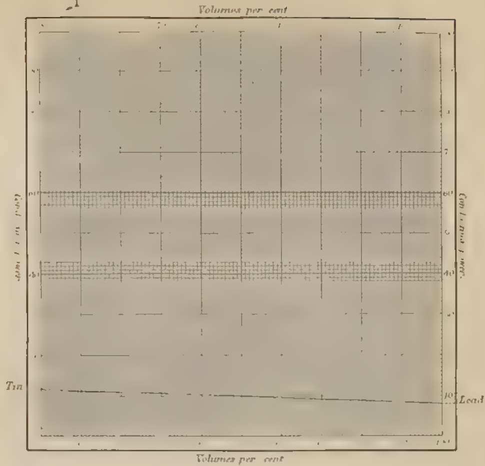
1


100
90
Conducting power.
Tin
90
80
70
60
50
40
30
20
10

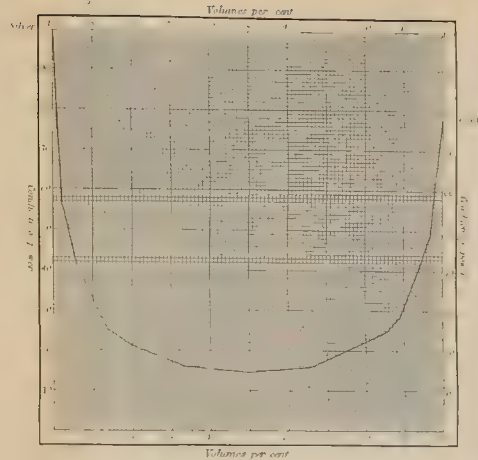
2


Copper
100
Conducting power.
90
80
70
60
50
40
30
20
10

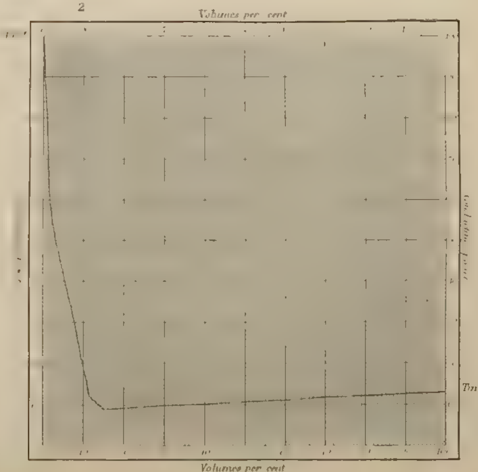
1


Volumes per cent
60
40
Tin
Lead
Volumes per cent

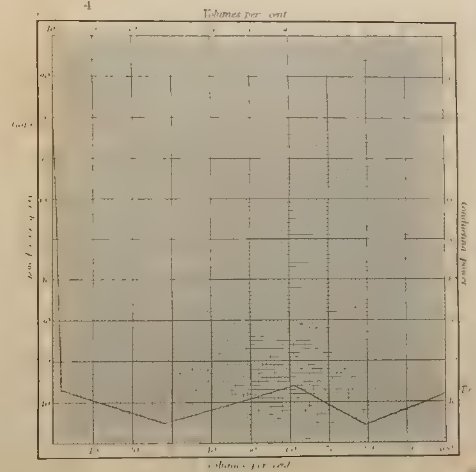
3


Volumes per cent
Silver
Volumes per cent

2


Volumes per cent
Tin
Volumes per cent

4


Volumes per cent
Conducting power

slowly, different parts of the alloy will be found to contain different percentages of metal.

Having shown, by examples taken from different groups of alloys, how their chemical nature may be indicated by the determination of their conducting-power for electricity, I will proceed to classify the solid alloys composed of two metals, according to their chemical nature:—

1. As solidified solutions of one metal in another, we have the lead-tin, cadmium-tin, zinc-tin, lead-cadmium, and zinc-cadmium alloys.

2. As solidified solutions of one metal in the allotropic modification of the other, the lead-bismuth, tin-bismuth, tin-copper, zinc-copper, lead-silver, and tin-silver alloys.

3. As solidified solutions of the allotropic modification of metals in one another, the bismuth-gold, bismuth-silver, palladium-silver, platinum-silver, gold-copper, and gold-silver alloys.

4. As chemical combinations, the alloys the composition of which is represented by $Sn_5 Au$, $Sn_2 Au$, and $Au_2 Sn$.

5. As solidified solutions of chemical combinations in one another, the alloys whose composition lies between $Sn_5 Au$ and $Sn_2 Au$, and $Sn_2 Au$ and $Au_2 Sn$.

6. As mechanical mixtures of solidified solutions of one metal in another, the alloys of lead and zinc when the mixture contains more than 1·2 per cent. lead or 1·6 per cent. zinc.

7. As mechanical mixtures of solidified solutions of one metal in the allotropic modification of the other, the alloys of zinc and bismuth when the mixture contains more than 14 per cent. zinc or 2·4 per cent. bismuth.

8. As mechanical mixtures of solidified solutions of the allotropic modifications of the two metals in one another, most of the silver-copper alloys.

With regard to the hypothesis which I have brought forward in this Report, I would point out that it serves to explain the phenomena which take place when some metals are alloyed with others. The assumption of the existence of the allotropic modifications of the metals explains the turning-points of the curves which represent alloys containing very small percentages of the one metal; for at these points it is assumed that the conversion into the allotropic condition is complete. It must be borne in mind that most of the other physical properties of the metals belonging to Class B are also altered in a marked degree by the addition of a small percentage of another metal: take, for instance, the case of gold or silver, and alloy them with traces of tin or lead, and how altered are the tenacity and ductility of the alloy so formed!

Until, however, the allotropic modifications have been isolated, the assumption made in this Report must remain an hypothesis. A fact may be mentioned in its support; namely, sulphur when heated to a temperature of 60°, and then cooled rapidly, is converted into an allotropic modification. Dietzenbach has observed that this conversion is brought about at 120° if $\frac{1}{400}$ of iodine be added to the sulphur, showing that the presence of a small quantity of iodine has a marked effect on the conversion of sulphur into an allotropic condition.

It may be asked, How can we deduce the chemical nature of a series of alloys from the determination of a physical property such as their conducting-power for electricity? We reply, from this property taken alone it is impossible to draw any conclusion of the kind, but that since, in the case of those alloys whose constitution is known by direct chemical and other evidence (silver-copper (Levol), zinc-copper (Storer), gold-silver), their conducting-power is found to be such as their chemical constitution would lead us to expect, this property may legitimately be taken in evidence as to the nature of those alloys which have not been examined chemically, and that in this respect

the property in question stands exactly upon the same footing as other physical properties, such as specific volume, specific heat, isomorphism, &c., which do not directly indicate anything with regard to the chemical properties of bodies, but which, after having been found to bear a relation in very many cases to those properties, are safely taken as guides in drawing conclusions as to the nature of bodies whose chemical character is as yet unknown.

On the Chemical and Mineralogical Constitution of the Granites of Donegal, and of the Rocks associated with them.

By a Committee consisting of Robert H. Scott, Sir R. Griffith, Bart., and the Rev. S. Haughton, M.D., F.R.S., appointed at the Manchester Meeting, 1861.

The county of Donegal consists to a great extent of metamorphic rocks. However, in its southern portion there is a district in which strata belonging to the Carboniferous period are found. The granites of the county, which are the main subject of this report, are found in several localities. The most extensive appearance of rocks of this nature is in a tract whose longer diameter is about 30 miles in length, and coincides nearly exactly with the axis of the valleys of Gweebarra and Glenveagh, which traverses the county in a direction from N.E. to S.W. In Glenveagh the granitic district is confined to the valley itself, and is flanked on each side by other rocks; but as soon as we reach the head of that glen, we find that the granite extends over the whole country to the westward, and forms almost the entire coast from Bloody Foreland to the mouth of the Gweebarra River.

Closely connected with this tract of granite are the isolated patches of the same rock which are found at several points, such as Ardara, Urrismenagh (near Dunaff Head), and Ardmalin—all of them situated nearly along the line of the great valleys before mentioned. Granite also appears in small quantity in Fanad and Rossguill, and on the south coast of Arranmore Island. The granite of the Bluestack and Barnesmore Mountains, in the S.E. of the county, is very dissimilar in its appearance to that of the western district; and although they may be generalized in a map sufficiently under a common designation, yet, from internal evidence, we are not disposed to consider them to be connected with each other.

The other rocks which occur in the district which comes under our notice are gneiss, mica slate, quartz-rock, grit, crystalline limestone, and a variety of syenitic* rocks, which do not differ much from each other in chemical constitution, although they are very dissimilar in texture. The true gneiss (as distinguished from gneissose granite) and the mica slate are found chiefly in the south of the county.

Before we proceed to discuss the chemical composition of the granites, it may be well to give a sketch of the geological features of the district, as observed during the several tours made by the members of the Committee in pursuit of this investigation. On one of these Mr. Jukes, Local Director of the Irish Geological Survey, was kind enough to accompany us and give us the benefit of his valuable assistance and experience of similar rocks in Newfoundland.

* The term syenite is used for any coarsely crystalline rock containing, as its most important constituent, a hornblendic mineral, associated with a feldspar, and occasionally with quartz or mica, or both. Some analyses of these rocks are given in Table VI. p. 62.

We shall commence the description of the county with an account of the rocks observed in Innishowen, and proceed in a S.W. direction from that barony. In the north of Innishowen the rocks consist of grits, crystalline limestones, mica-slate, and a variety of igneous rocks (greenstones and syenites). The whole of these rocks are contorted considerably about Culdaff, and from that to Malin Head they exhibit a consecutive section, of which the dips increase as you go westward, the beds being nearly horizontal at Culdaff and along the shore towards Glengad Head.

The grits of this part of the county are true grits, not having been sufficiently metamorphosed to form quartzites until we reach a more westerly point. There are a few beds of potstone and soapstone scattered through the argillite beds, but they are not of so much importance as those found at Convoy, Crohy Head, and in other parts of the county.

There is also found in the mica-slate a series of beds of chalcedonic conglomerate, which is very characteristic of this district. Of this conglomerate the cement is micaceous, and the pebbles are mainly siliceous (of the chalcedonic variety), but consist also of feldspar and of portions of the mica-slate itself. Similar conglomerates to these are described by Mr. MacFarlane* as a characteristic feature of the Huronian Series of Canada, and of their Norwegian equivalents, called by Naumann the Tellemarken Quartz-formation, from the district of that name in the south of Norway. Keilhau† says of them, that they occur in repeated alternations with hornblende rock; the cement is micaceous, and the pebbles sometimes feldspathic, sometimes quartzose, and sometimes of still more varied natures. In some places, he says, the concretions are apparently imbedded fragments of the rock itself, as if it had been broken up and the pieces had been irregularly joined together.

A description of conglomerates similar to these is to be found in the Reports of the Geological Survey of Canada; and we are of opinion that similar conglomerates have been discovered by two of our number in Scotland, viz. by Sir R. Griffith at Anie, not far from Callander, and by Professor Haughton at the summit-level of the Crinan Canal.

It is very remarkable that the igneous rocks, which, as has been said before, are very abundant in the county, are undoubtedly cotemporaneous with the sedimentary rocks of Innishowen. This fact is observable along the coast, but it is noticeable in the most striking manner between Buncrana and Carndonagh, about five miles from the former place, the whole of the hills lying between Slieve Snaght and the Raghtin Mountains being composed of alternating beds of quartz-rock and syenite, dipping at a low angle to the eastward. This is beautifully exhibited in the mountain of Binmore, lying in the district of the Barr of Inch, close to the Mintiagh Lakes. This hill with the mountain Bulbin are terraced like the trap hills of Antrim; but on a close examination it is found that, although the whole face of the rock appears to be columnar, it consists of alternate beds of quartz-rock and syenite, as before described. The columnar structure of the former is due to the simultaneous development in it of three series of joints inclined to each other at angles approaching those of a regular hexagon. These joints are all

* We should here express our acknowledgments for the assistance we have derived from Sir W. Logan's and Dr. T. Sterry Hunt's "Report on the Rocks of Canada," now in process of publication by the Geological Survey of that country; and from Mr. MacFarlane's two papers "On the Primitive Formations in Norway and Canada," 'Canadian Naturalist and Geologist' for 1862.

† Gæa Norvegica, pp. 430, 432.

of them traceable in other parts of the county, but it is only here that hey assume a development of such importance.

On passing west from Buncrana towards Dunaff Head, through the gap of Mamore, it is found that, as we approach the granite at Urrismenagh, the dip of the beds increases from 45° to nearly absolute verticality. The granite of Urrismenagh does not present many features of interest, as the rocks in immediate contact with it are quartzose, and therefore unlikely to yield accidental minerals.

The rocks lying between Rathmullen and Milford are similar to those which have been already described as occurring in Innishowen; however, the granite of Kindrum in Fanad deserves a special notice, as it is somewhat remarkable in its character, resembling the variety which is found at Ardara and also in the island of Arranmore, as will be noted hereafter. It is, in general, white, and contains a large quantity of black mica and of sphene; but there is a considerable quantity of a reddish granite found disseminated through it. The nature of this granite differs materially from that of the typical granite of the central valley. It is a remarkable fact, that all the localities in which this white "sphene-granite" (as we call it, from the great abundance of that mineral in it) occurs are situated at a distance from the central granitic area.

At Glen, which is situated close to the head of Sheephaven, and at the northern extremity of the lake of that name, the central granite ends rather abruptly; it is flanked on the east side by a very peculiar, highly micaceous gneiss, called in the district "black granite." Of this rock there are two varieties, one of which contains a reddish feldspar, the other a grey one, this latter exhibiting the striæ of an anorthic feldspar. The granite itself is very similar in its appearance to that which occurs near Doocharry Bridge in the Guibarra valley, and is characterized by the presence of the two feldspars, orthoclase and oligoclase, the orthoclase being of a flesh-red colour.

Close to Glen, at Lackagh Bridge, on the road to Creeshlagh, we meet with a very remarkable illustration of the nature and relations of the rocks throughout the whole county. A series of quartzites and hornblende slates are met with, the latter passing gradually into syenites. Their strike is E. 5° N., and their bedding vertical. They are traversed, along the strike, by a series of veins of granite, which rarely cross a bed, but still preserve the character of veins, not of beds, as they are decidedly not lenticular.

Appearances precisely similar to this have been observed at Toberkeen, and at Stackamore, about half a mile north of Leabgarrow in Arranmore. The bearing of this fact on the geology of the county will be again referred to.

The chief point noticeable about the neighbourhood of Dunfanaghy is the extreme development of a highly crystalline syenite, containing a large proportion of titaniferous magnetic iron. The octahedral crystals of this mineral are very noticeable on the weathered surface of the rock. The best specimens are obtainable close to M'Swyne's Gun, at Horn Head. The magnetite also occurs in a rock composed mainly of black mica—an occurrence very similar to that which it has in some parts of Norway.

The quartz-rock of Horn Head is highly characteristic, being eminently flaggy in its nature, and splitting into long fluted blocks resembling *Sigillariæ* at first sight. This variety of the rock contains a considerable quantity of feldspar disseminated through it in grains, as if in a porphyry. The same sort of rock is found also at Crohy Head. There is another variety of quartz-rock, which contains mica in large quantity as extraneous element, and is found to occur extensively in Arranmore. These two varieties of quartz-rock

have been noticed as occurring both in Norway and in Canada. In the former locality Keilhau especially refers to the feldspathic variety as being easily disintegrable into sand. It is a remarkable confirmation of this, that on the flat summit of Muckish Mountain, which is itself composed of this quartz-rock, there is a very large deposit of siliceous sand in a condition of nearly absolute chemical purity.

The other variety is mentioned in the Report of the Geological Survey of Canada before referred to, in the following words:—"The quartzites have sometimes the aspect of sandstones, and at other times lose their granular texture and become a vitreous quartz. Not unfrequently the quartzite is thin-bedded and even schistose in its structure; and it sometimes holds a little mica, passing into a variety of mica-schist." In Mr. MacFarlane's paper, he alludes to both varieties as occurring in Norway.

There is found throughout the county a considerable quantity of highly crystalline metamorphic limestone, which is usually of a bluish colour. No traces of fossils have as yet been discovered in it, although at one locality, Culdaff, concretions have been found which have been supposed by some persons to be the half-obliterated remains of corals. We do not see any reason for attributing an organic origin to them. The limestone-beds which occur in immediate proximity to the granite, but not in actual contact with it, are converted into white marble. Those which are found in contact with the granite have undergone a further alteration, several minerals having been generated in them. Among these we may mention garnet, idocrase, epidote, tremolite, &c.

In almost all the localities where the limestone occurs in the granite, we find, in immediate contact with the limestone, a rock which we have termed "sphene-rock," as it is characterized by the great abundance of that mineral. It consists of orthoclase, green pyroxene, and quartz; and in it we have discovered minute crystals of blue apatite, and in one locality (Glenleheen) a great abundance of white scapolite.

Dr. T. Sterry Hunt, on seeing our sphene-rock, recognized it at once as an old friend. He says of it, "Associated with the Laurentian limestones, there are frequently found beds of a coarse-grained rock made up of white feldspar and dark-green pyroxene with brown sphene, and occasionally with quartz. The feldspar is found to be orthoclase." The rock is also well known to the quarrymen in Canada as the next bed to the limestone.

Although this seems to point to a certain similarity between the limestones of Donegal and those of the Laurentian rocks of Canada, we should say that we have not been able to discover any deposits of either apatite or graphite in appreciable quantity. These minerals are stated to accompany the Laurentian limestones, and to be an important feature in the rocks belonging to that series.

In order to examine the granite more thoroughly, we have crossed it several times, and have found the results of all the sections to be nearly identical. The granite is, in general, fine-grained; but there is one important district to which this statement will not apply, viz. that on the west coast, which comprises Dunglow, Annagary, and Arranmore Island. In this part of the county the rock is coarsely crystallized; and it is a remarkable fact that the same district is further characterized by the appearance in it of a series of joint-planes, which do not coincide with those observed in other parts of the county. Attention has already been drawn to this fact by Professor Haughton, in a paper in the Quarterly Journal of the Geological Society of London, vol. xviii. p. 405.

In the very heart of its area, the granite, judging from hand-specimens, is

true granite; but when seen in the field, it is found to be stratified, the strike of the beds agreeing with that of the uncontorted sedimentary strata of the country, and the dip being nearly constant in amount, and uniformly to the eastward. In addition to these granitic beds there are numerous others (which become more abundant as you approach the edge of the district) which would be pronounced gneiss even from an examination of hand-specimens. This fact, which has been abundantly confirmed by observations in various localities, places the gneissose character of the rock, as a whole, beyond a doubt. The gneiss on the eastern edge of the granite, especially near Fintown and near Trawenagh Bay, is remarkable for the extraordinary development of crystallized orthoclase, of a red colour, which is to be seen in it, giving it an appearance very similar to that of the feldspar-veins at Castle Caldwell, which will be mentioned further on.

As a further illustration of the gneissose character of the granite, we may draw attention to the fact that, in numerous localities, portions of highly contorted gneiss are found actually within the granite. This is the case at Bunbeg, Lough Anure, Annagary, at the head of Glenveagh, above Gartan Abbey, at Toberkeen, Lough Pollrory, near Trawenagh Bay, Glenleheen, and near Lough Errig. These fragments of gneiss are sometimes of slight extent; sometimes, as at Lough Errig, they extend for 40 or 50 yards. Such an appearance as this is usually accompanied by the presence in the granite of highly crystalline limestones. These occur at the head of Glenveagh, again under Altahostia, halfway down the lake, at Glenveagh Bridge, and at the Gap of Barnesbeg. At Glenleheen we found that the limestone occurred in four distinct beds, possessing a strike of E. 5° N., which is coincident with that obtained from the rocks at Lackagh Bridge. The appearance in each locality is not absolutely continuous; but their identity of strike in different localities points to the existence of four distinct parallel beds. The three deposits of limestone in Glenveagh probably belong to the same bed, of which the continuity has been interrupted.

It is worthy of notice that this occurrence of non-granitic rocks in the granite is not strictly confined to the district where the texture of the rock is most decidedly gneissose, as in some of the localities (such as Toberkeen, Annagary, and Lough Anure) the limestone is found in contact with very coarse-grained granite. However, in this district there is a series of small patches of limestone extending in a curved line from Bunbeg towards Crohy Head and apparently bounding the district of Dunglow, in which the coarse-grained granite occurs.

In illustration of this relation of the rocks to each other I may again quote Mr. MacFarlane, who says, after giving a synopsis of the rocks to be met with in the Primitive Gneiss of Norway, which he compares to the Laurentian Series of Canada:—

"As to the mode in which these rocks are associated with each other, the whole of them are arranged in parallel layers or zones, side by side, underlying or else overlying each other. Hitherto no regular succession of rocks has been marked; they appear to be interstratified with each other without rule. The granitic masses are partly conformable with the parallel masses of the schistose rocks, and partly occur irregularly. It has been remarked that, when the granite becomes more or less gneissoid, its masses are regularly interstratified with the other schistose rocks; but where the granite is totally free from all traces of gneissoid texture, the form in which it occurs deviates more or less from that of layers or beds. A remarkable instance of this is described by Keilhau as occurring near Norefield*. There he saw a mass of

granite, which on the whole was gneissoid and bedded, gradually change at a certain place into a perfect granite, and then, in complete uninterrupted continuity, pierce the rock in the form of a dyke. Another instance is mentioned of a granite rock occurring in the schistose rocks † 'partly in very regular layers, partly as isolated knolls and lumps, and partly as a multitude of veins, which in several places run through large portions of the neighbouring mountains as a close network.' In spite of this, however, this granitic rock showed, in many places, a gneissoid structure. The relations of the hornblende schists and greenstones resemble those of the granite. The hornblende schist is regularly interstratified with the gneiss, mica-schist, and other rocks."

We have been induced to make this long quotation, owing to the great analogy which it shows to exist between the district which comes under our notice and the Scandinavian peninsula. We have learnt from Mr. Jukes that he has observed similar phenomena on the coast of Newfoundland; and they were observed and noticed by Sir R. Griffith upwards of twenty years ago, when he was examining the county of Donegal for the purpose of publishing his Geological Map.

The fact that in Donegal this gneissose granite is apparently intrusive in many places is abundantly proved by the occurrence of granite dykes cutting across the limestone at Drumnaha Gap, near Fintown, and in Dunlewy marble-quarry. It appears also in a striking manner at Pollnacally, near Trawenagh Bay, where the granite is intrusive into quartz-rock, and sends veins into hornblende-rock; and also at several localities on the south shore of Arranmore Island.

Among the argillaceous beds which lie near the granite are found several of anthophyllite slate, which pass gradually into soapstone and potstone, as at Crohy Head, Gartan Abbey, Convoy, and elsewhere. At Crohy they are associated with a mass of light-green serpentine, which unfortunately does not occur in a sufficiently massive condition to be available for commercial purposes. The soapstone too is rendered impure by the presence of iron pyrites, to such an extent that its utility as a lubricating agent is seriously impaired.

Arranmore Island consists mainly of quartz-rock of the micaceous variety, with interstratified and intrusive igneous rocks. At the S.E. corner of the island, from Leabgarrow to the chapel at Illion, we find a coarse-grained red granite, which takes a fine polish, and is remarkably free from joints. One block, measuring superficially 90×20 feet, is exposed on the sea-shore. Between this point and Torboy at the S.W. corner of the island, a considerable portion of the coast is formed of white sphene granite, like that at Ardara. At Tordhu it contains some syenite and gneiss, the whole forming in places a network of veins, as was so well described by Keilhau in the quotation we have already made from 'Gæa Norvegica.'

This granite, as well as the other rocks of the island, and the granite near Dunglow, is penetrated by numerous dykes, some of ordinary trap, others of amygdaloidal pitchstone, and some of felstone-porphyry.

In the S.W. part of the county, extending down to Teelin Head, we meet with mica-slate, abounding with iron-pyrites. Through this rock, especially in the neighbourhood of Ardara, there is disseminated a large quantity of syenite passing into hornblende rock.

The granite of Bluestack and Barnesmore, as has been said before, differs in its character from that of the Gweebarra Valley, as it appears to consist of red orthoclase and quartz, with very little mica. It is traversed by numerous

* Gæa Norvegica, p. 367. † Ibid. p. 343.

dykes of pitchstone, some of which are amygdaloidal, and also by veins of amethyst and of smoky quartz, the latter in very large crystals. No limestone has as yet been found in contact with it, nor have we been able to detect any non-granitic rocks within its area.

The district to the S.E. of the town of Donegal, extending to the shore of Lough Erne, near Belleek, and comprising part of the county Fermanagh, consists of a gneiss which is different in texture from that of other parts of the county. Along its northern edge we find mica-slate, abounding with large garnets, kyanite, schorl, and in some places sphene. In another locality, Aghadoey, we find dark-green serpentine with garnet rock; and the whole district is penetrated by numerous veins of granite referable to two distinct types:—

A. Veins containing quartz, pink orthoclase, white mica, black mica, and schorl. Crystals large.

B. Veins containing quartz, pink orthoclase, yellowish-green oligoclase, black mica, with garnets, molybdenite, and copper pyrites. Crystals moderately large.

As regards the probable age of the Donegal metamorphic strata, the Committee do not wish to bring forward any statements in this Report, as we are of opinion that the district is too limited in extent for any safe reasoning of this nature to be based on its examination. It appears certain that rocks of the same nature occur in part of Connaught and in the west of Scotland; and it is to be hoped that the labours of the Irish Geological Survey in the one case, and of the Scotch Survey in the other, will put us in possession of data which they alone are in a position to ascertain, and which will finally determine the relation of these strata to the overlying fossiliferous rocks.

Before we conclude this portion of our Report, we are bound to express the obligations of the Committee to William Harte, Esq., C.E., the county surveyor of the western district of the co. Donegal, who has been indefatigable in his exertions in aid of the researches which have been carried on; and also to J. Vandeleur Stewart, Esq., D.L., of Rock Hill, near Letterkenny, and to the Rev. Frederick Corfield, of Templecrone, from both of whom the Committee have derived valuable assistance.

Chemical Constitution of the Granites.

In investigating the chemical constitution of the granites of Donegal, we have analyzed fifteen specimens of granitic rocks from that county, and, in addition to these, we are enabled to lay before the Association the analyses (Nos. XVI., XVII., Table V.) of two specimens selected from a series of Scotch granites, for which we are indebted to the kindness of Sir R. I. Murchison. These specimens were selected in consequence of their close resemblance to some of those which we find in Ireland. We have further analyzed some of the syenites, and several specimens of the simple minerals found in the granites and the other rocks.

The result of most of these analyses have already been published in the course of last year by one of our number, Prof. Haughton, in the 'Quarterly Journal of the Geological Society of London' (vol. xviii. p. 403), as a portion of his "Experimental Researches on the Granites of Ireland." We shall first speak of the individual minerals, then give the analyses of the rock-masses, and finally give the results of the mathematical investigation of the mineralogical constitution of the granites.

Minerals of the Granite of Donegal.

The minerals of the granite of Donegal may be divided into Constituent and Accidental Minerals.

The Constituent Minerals (A) are—

1. Quartz. 3. Oligoclase. 5. White Mica.
2. Orthoclase. 4. Black Mica. 6. Hornblende (sometimes).

Of these the first four are always present, and easily distinguishable from each other; the fifth mineral, white mica, is found locally abundant, particularly in veins, associated with special accidental minerals; and the sixth mineral, hornblende, is found intimately mixed with black mica [as in lepidomelane, *Soltmann*] in the more basic varieties of the granite.

The Accidental Minerals (B) are—

1. Sphene. 3. Beryl. 5. Molybdenite.
2. Schorl. 4. Garnet. 6. Copper pyrites.

Of these latter we may say that sphene is the most characteristic, as it is found throughout the county. It also occurs in considerable quantity in the granite of Galway, which resembles that of Donegal in many respects.

A. *Constituent Minerals.*

1. *Quartz.*—The quartz entering into the composition of the granite is of the usual grey variety; when found in veins, it sometimes forms fine black crystals, as at Brown's Hill, Barnesmore, and sometimes smaller crystals of a rose-colour, as at Barnesmore and Sheskina-roan, sometimes of amethyst, as in Tawnawully Mountain.

2. *Orthoclase.*—The orthoclase of the Donegal granite is generally red, but sometimes white: the following analyses show its composition:—

TABLE I.—*Orthoclase of the Donegal Granite.*

	1.	2.	3.
Silica	63·20	62·80	63·60
Alumina	19·72	16·84	19·32
Iron (peroxide)*	0·28	0·96	0·80
Lime	2·59	4·95	0·72
Magnesia	0·09	0·11	0·14
Soda	0·06	0·46	1·84
Potash	16·30	14·91	13·55
Totals........	102·24	101·03	99·97

No. 1. *Glenveagh.*—White, opaque, milky, forming crystals in the granite.

No. 2. *Croaghonagh, near Lough Mourne, above Barnesmore Gap.*—Found in great bunches, isolated, in the middle of a very close-grained mica-schist, or gneiss of very fine grain. The feldspar is bright red, and associated with milky quartz, containing specular micaceous iron-oxide and chlorite. The diameters of some of the bunches are 5 ft. They are probably the terminations of veins 2 ft. wide, ending in *carbonas* in the gneiss, and have all the appearance of having been filled by aqueous action at a high temperature.

No. 3. *Castlecaldwell.*—Found associated with white mica, quartz, black mica, and occasionally schorl and iron-pyrites, in veins penetrating the fine-grained gneiss of the district. The feldspar of these veins is worked for the manufacture of china, and burns white, although pink and red in the vein.

* In all cases the determination of the protoxide of iron, if present, has been effected by Margueritte's method.

3. *Oligoclase.*—The oligoclase of Donegal is of a honey-waxy-greenish grey colour, and is easily distinguished from the orthoclase which accompanies it by its colour and by the fine striated lines that mark certain of its surfaces of crystallization, and prove it to be an anorthic feldspar. The following analyses give its composition:—

TABLE II.—*Donegal Oligoclase.*

	No. 1.	No. 2.	No. 3.
Silica	60·56	59·28	62·40
Alumina	24·40	22·96	23·60
Iron (peroxide)	0·40	1·94	....
Lime	5·96	4·65	5·62
Magnesia	0·04	0·21	0·08
Soda	6·46	6·48	7·04
Potash	1·76	2·38	1·66
Iron (protoxide)......	....	0·10	....
Manganese (protoxide)	....	0·32	....
Totals........	99·58	98·32	100·40

No. 1. *Garvary Wood, near Castlecaldwell, Co. Fermanagh.*—Pearl-grey, translucent; in veins in gneiss; associated with black mica, some orthoclase (pink), copper-pyrites, and molybdenite.

No. 2. *Precise locality unknown.*—The specimen from which it was taken belongs to that variety of granitic syenite into which the granite of Donegal sometimes passes, as at the Black Gap, Pettigo.

No. 3. *Knader, near Ballyshannon.*—This analysis has been made by Professor Apjohn, and was communicated by him to the authors. The specimen is more opaque than that from Garvary, and of a lighter colour.

4. *Black Mica.*—Black mica forms in Donegal, as in the Mourne Mountains, a constant and important constituent of the granite; it is always present, and becomes green when decomposition sets in.

The following analyses show its chemical composition:—

TABLE III.—*Black Mica of Donegal.*

	No. 1.	No. 2.	No. 3.	No. 4.
Silica	36·16	36·20	44·40	31·60
Alumina	19·40	15·95	21·52	19·68
Iron (peroxide)	26·31	27·19	10·72	23·35
Lime	0·58	0·50	2·70	0·45
Magnesia	4·29	5·00	6·14	7·03
Soda	0·48	0·16	0·74	0·74
Potash	9·00	8·65	6·18	3·90
Iron (protoxide)......	0·62	0·64	3·96	4·04
Manganese (protoxide)	0·40	1·50	1·28	1·20
Loss by ignition......	2·40	3·90	1·20	8·68
Totals........	99·64	99·69	98·84	100·67

No. 1. *Glenveagh.*—Occurs in coarse gneiss, containing also orthoclase and oligoclase.
No. 2. *Ballygihen.*—Occurs in granite, in ½-inch plates, ¼ inch in thickness.
No. 3. *Garvary Wood.*—Associated with oligoclase, orthoclase, and molybdenite, in veins in gneiss.
No. 4. *Castlecaldwell.*—Associated with orthoclase and schorl in veins in gneiss. This mica is green, and is obviously the black mica much decomposed.

The differences between these analyses are very great, and it is evident that No. 4 is decomposing; it therefore cannot be considered as a fair specimen of the mineral. As to the discrepancies between the other three analyses, we find that Rammelsberg ('Mineralchemie,' 1860, p. 668) gives, in his list of magnesia-micas, minerals in which the amount of magnesia ranges from 3 to 30 per cent. For the purposes of the future investigation of the mineralogical composition of the granites, we shall take the mean of the two analyses Nos. 1 and 2, each of which represents the constitution of a mica taken from the central granitic area in Glenveagh and its vicinity.

5. *White Mica.*—This mineral, although not a constituent mineral of the granite of Donegal, occurs frequently in veins, and is always associated with orthoclase, sometimes with schorl and beryl. It is biaxial, and resembles the margarodite of Leinster already described (Quart. Journ. Geol. Soc. Lond. vol. xii. p. 171).

The following analyses show its composition:—

Table IV.—*White Mica of Donegal.*

	No. 1.	No. 2.
Silica	44·80	45·24
Alumina	29·76	35·64
Iron (peroxide)	8·80	2·24
Lime	0·45	0·51
Magnesia	0·71	0·71
Soda	0·32	0·54
Potash	12·44	10·44
Iron (protoxide)	......	0·70
Manganese (protoxide)	0·48	0·24
Loss by ignition	2·00	4·00
Totals	99·76	100·26

No. 1. *Castlecaldwell.*—Found in veins of quartz and pink orthoclase, containing schorl and decomposing plates of black mica. Biaxial (72° 20′). Angle of plate=125°.
No. 2. *Near Ballygihen, in Dooish Mountain.*—In veins in the granite, not associated with black mica; in plates ¾ inch wide, ¼ inch thick. Biaxial (62° 10′ to 65° 10′). Angle of plate=120°.

6. *Hornblende.*—The granite of Donegal varies much in texture and appearance, as might be expected from its gneissose character. It occasionally passes into a granitic syenite, composed of hornblende, oligoclase, and a little quartz and sphene. The composition of the feldspar of this rock has been already given; that of its hornblende is as follows:—

Hornblende of Donegal Granitic Syenite.

Silica	47·25
Alumina	5·65
Iron (peroxide)	19·11
Lime	11·76
Magnesia	11·26
Soda	0·98
Potash	1·04
Iron (protoxide)	0·94
Manganese (protoxide)	1·70
	99·69

B. *Accidental Minerals.*

1. *Sphene.*—This mineral is very like the clove-brown sphene of Norway: it is found in the granite, when the latter becomes basic, containing much black mica and oligoclase; but it is principally found in a rock formed of a paste of quartz and feldspar, that often lies between the granite and limestone of the metamorphic rocks of Donegal. This is especially observable at Annagary and Barnesbeg, where this rock is so abundant as to become entitled to the name of sphene-rock; and it cannot be distinguished from similar rocks from Norway.

2. *Schorl.*—This mineral accompanies orthoclase in veins, and is often curved and cracked, showing the wider openings of the fissures next the convex side, and filled with quartz, as if the curvature of the schorl and the filling of its fissures with quartz were the result of an action that took place after the deposition of the mineral.

3. *Beryl.*—The only known locality for beryl in Donegal is Sheskinaroan, near Dunglow. It is green, with occasionally a shade of blue, and occurs both in reefs of quartz traversing the granite along its leading joints and also in the granite itself, which, in this case, becomes very quartzose, and its black mica disappears, giving place to fine rhombs of margarodite.

The beryl of Donegal has never, so far as we know, been analyzed—a circumstance which may give some additional value to the following analysis:—

Beryl, from Sheskina-roan, Co. Donegal. Sp. gr. = 2·686.

Silica	65·52
Alumina	17·22
Glucina	13·74
Iron (peroxide)	1·53
Lime	0·43
Magnesia	0·13
Water	0·90
	99·47

4. *Garnet.*—This mineral, in bright ruby-coloured crystals, is found in the granite of Glenties, Annagary, and other localities. Form dodecahedral.

5. *Molybdenite and Copper-pyrites.*—These minerals are found in veins of granite, at Garvary Wood, near Castlecaldwell, associated with oligoclase and black mica.

Minerals occurring in the Non-granitic Rocks of Donegal.

By reference to the Appendix to this Report, it will be seen that the minerals which have been hitherto observed in the county are about sixty in number.

Of these a great number are of minor importance, and only a few have been analyzed, in consequence of the difficulty of obtaining them in a sufficiently pure state for that purpose. This has been the case with the sphene and the scapolite. Allusion has been made to the frequency with which potstone and soapstone are met with in the county, and we have therefore considered it to be of interest to analyze both it and the silky crystals which are found in it, especially at Crohy Head.

	No. I. Crystals.	No. II. Massive soapstone.
Silica	62·52	60·24
Alumina	0·36	1·12
Iron (peroxide)	1·24	1·48
Manganese	trace	trace
Lime	trace	0·00
Magnesia	34·64	35·14
Soda	0·36	0·41
Potash	0·01	0·07
Water	0·40	1·00
	99·53	99·46

From these analyses it will be seen that the mineral is a true anhydrous talc; and this fact is the more interesting inasmuch as we can trace, both at Gartan Abbey and at Crohy, the gradual passage of this mineral into anthophyllite, with the crystalline form of which mineral the radiated silky crystals of that under examination are evidently closely connected.

Rammelsberg does not include among his analyses of the hornblende family any which is absolutely free from lime, although Scheerer's analysis of the asbestus from St. Gotthardt (Mineralchemie, p. 475, No. 7) is nearly so, and this mineral accompanies tremolite. On the other hand, the presence of the

TABLE V.—*Chemical Composition of Donegal Granites.*

No.	Silica.	Alumina.	Iron, peroxide.	Iron, protoxide.	Lime.	Magnesia.	Soda.	Potash.	Manganese, protoxide.	Water.	Totals.
I. Ardmalin	70·00	16·36	2·80	0·08	1·12	0·71	4·13	4·66	...	...	99·86
II. Urrismenagh	65·80	12·80	6·64	0·18	2·92	1·78	4·16	4·40	...	1·20	99·88
III. Glen	68·96	17·40	2·52	...	2·80	0·41	3·03	5·25	...	...	100·37
IV. Glen	58·44	20·00	6·44	2·05	4·72	1·57	3·81	2·82	...	...	99·85
V. Glenveagh	69·36	16·00	3·03	0·30	2·29	0·54	4·17	4·47	...	...	100·16
VI. Glenveagh	68·00	16·80	3·68	0·65	4·05	0·95	4·32	2·04	...	...	100·49
VII. Poison Glen	68·20	15·96	3·69	1·00	2·92	0·78	3·75	4·14	...	...	100·44
VIII. Poison Glen	70·64	15·64	2·64	...	2·47	0·15	3·81	4·53	...	...	99·88
IX. Doocharry Bridge	72·24	14·92	1·63	0·23	1·68	0·36	3·51	5·10	0·32	...	99·99
X. Barnesmore	73·60	13·80	2·00	...	0·79	0·50	4·29	5·22	...	...	100·20
XI. Arranmore	68·80	16·40	2·60	0·65	1·75	0·85	3·78	5·31	...	...	100·14
XII. Tory Island	69·20	16·40	2·09	1·00	1·03	0·85	4·20	5·22	...	...	99·99
XIII. Ardara	55·20	19·28	6·08	0·46	5·08	3·66	4·63	3·17	0·96	0·64	99·16
XIV. Dunlewy	75·24	13·36	0·60	...	2·25	0·14	4·86	3·27	...	...	99·72
XV. Annagary	73·04	15·20	...	...	1·60	0·07	2·88	7·32	...	...	100·11
XVI. Strontian	62·09	17·60	4·78	0·74	4·95	3·17	4·08	3·25	0·40	...	101·06
XVII. Tobermory, Mull	70·60	16·40	1·52	0·36	2·47	1·00	4·14	4·29	0·48	...	101·26

manganese, which was clearly detected in both analyses, would tend to bring the Crohy specimen out of the type of talc and into that of hornblende.

Among the other more interesting minerals which have been found, we may mention molybdenite in crystalline plates, fibrolite, kyanite, schorl (extremely abundant), and the minerals which have been already mentioned as occurring in the altered limestones.

I. *Ardmalin, near Malin Head.*—Coarse-grained granite, composed of
- (*a*). Quartz; very conspicuous ($\frac{1}{4}$ in. crystals).
- (*b*). Red orthoclase feldspar ($\frac{1}{4}$ in. crystals).
- (*c*). Green mica; in small nests, resembling chlorite.

II. *Urrismenagh, near Dunaff Head.*—Medium-grained granite, containing—
- (*a*). Quartz; not very visible.
- (*b*). Pink feldspar; probably orthoclase ($\frac{1}{8}$ in. crystals).
- (*c*.) Grey feldspar; probably oligoclase ($\frac{1}{8}$ in. crystals).
- (*d*). Black mica; $\frac{1}{16}$ in. crystals; occasionally passing into a dark blackish-green mica, in small nests and resembling a mixture of chlorite and hornblende.

III. *Glen.*—Coarse-grained gneissose granite, containing—
- (*a*). Quartz; scarcely visible, broken, transparent, grey.
- (*b*). Red feldspar; probably orthoclase, forming large crystals (partly made up of pink translucent feldspar, with bright reflexion), dull waxy lustre, opaque.
- (*c*). Whitish translucent feldspar; probably oligoclase, and quite distinct from (*b*).
- (*d*). Green mica; abundant in streaks alternating, as in gneiss, with crystalline sheets of red and pink feldspar.

IV. *Glen.*—Coarse-grained gneissose granite, apparently in beds in the granite No. III., and containing—
- (*a*). Whitish feldspar; anorthic, semiopaque, and sometimes in macles, probably oligoclase (crystals $\frac{1}{2}$ in. by $\frac{1}{4}$ in.).
- (*b*). Jet-black mica; in great abundance, probably equal to the feldspar, which occurs in rounded masses imbedded in the black mica, which itself occurs in streaks as in gneiss.

V. *Glenveagh.*—Beautiful, coarse-grained, porphyritic granite:—
- (*a*). Feldspar; conspicuous, pink (crystals $\frac{1}{2}$ in. to $\frac{3}{4}$ in.), orthoclase.
- (*b*). Quartz; inconspicuous, grey, transparent, with rounded angles.
- (*c*). Mica; jet-black, abundant in minute grains; the black mica and pink feldspar give character to the rock.

VI. *Glenveagh.*—Fine-grained gneissose granite:—
- (*a*). Quartz, scarcely visible, grey.
- (*b*). Feldspar; white, sugary, facets rare, and, when they do occur, semitransparent—probably oligoclase.
- (*c*). Mica; perfectly black, high lustre.

VII. *Poison Glen.*—Medium-grained granite:—
- (*a*). Quartz; grey, not prominent.
- (*b*). Feldspar; pink, in large crystals ($\frac{1}{2}$ in. by $\frac{1}{8}$ in.), semitransparent, predominant; orthoclase.
- (*c*). Mica; jet-black, bright lustre.

VIII. *Poison Glen.*—Coarse-grained granite.

(*a*). Quartz; conspicuous, grey.

(*b*). Feldspar; pink, in large crystals ($\frac{1}{2}$ in. by $\frac{1}{4}$ in.), transparent, bright calcspar lustre, set in a paste of quartz and pinkish feldspar.

(*c*). Mica; an occasional speck of green mica, probably not $\frac{1}{2}$ per cent.

IX. *Doocharry Bridge.*—Medium-grained granite, tending to become porphyritic.

(*a*). Quartz.

(*b*). Feldspar; orthoclase, pink, in $\frac{1}{2}$ in. crystals.

(*c*). Feldspar; oligoclase, grey, in $\frac{1}{8}$ in. crystals.

(*d*). Mica; black, in small grains or specks, and in small quantity.

X. *Barnesmore Gap.*—Coarse-grained reddish granite, of platy structure, one-inch slabs.

(*a*). Quartz; very prominent, grey, occupying a surface *only* inferior to the red feldspar.

(*b*). Feldspar; pale red, uniform in texture, with some well-developed cleavages, not very brilliant.

(*c*). Mica; green, very compact, with few leaves, passing into chlorite-earth: this chloritic earth covers the joint-surfaces ($\frac{1}{20}$ in. to $\frac{1}{10}$ in.), and is visible in all such partings. It is very difficult to distinguish the green mica from hornblende.

XI. *Arranmore Island.*—Porphyritic granite; feldspar predominating.

(*a*). Quartz; easily visible, abundant, grey.

(*b*). Feldspar; reddish, in distinct crystals ($\frac{1}{2}$ in. by $\frac{1}{4}$ in.), cleavage-planes distinct, with bright lustre, semitransparent.

(*c*). Mica; black; when seen on the edge, it resembles hornblende, of which, however, there is not a particle in the rock: facets of mica difficult to see, but having a very brilliant reflexion; subordinate to both the quartz and feldspar.

XII. *Tory Island.*—Coarse granite, almost entirely composed of quartz and feldspar, platy structure, one-inch slabs.

(*a*). Quartz; conspicuous, crystals ($\frac{1}{2}$ in.), grey.

(*b*). Feldspar; uniform red, with cleavage-planes of dull lustre, orthoclase.

(*c*). Mica; greenish, sometimes white, in occasional very small plates.

XIII. *Ardara.*—Coarse-grained gneissose granite:—

(*a*). Quartz; small grains.

$\left.\begin{array}{l}(b).\ \text{Feldspar; pink orthoclase}\\(c).\ \text{Feldspar; grey oligoclase}\end{array}\right\}$ in lumpy masses.

(*d*). Mica; black, in large quantity, giving a gneissose appearance to the rock.

Sphene occurs disseminated in small crystals.

XIV. *Dunlewy.*—Consists of quartz and feldspar intimately blended together and very similar in colour, whitish grey. In this paste are numerous crystals of feldspar (orthoclase) with definite ($\frac{1}{5}$ in.), lustrous, smooth faces. Also occasional stains of greenish mica, looking like

chlorite, and small crystals of garnet. This granite occurs immediately beside the limestone marble of Dunlewy quarry.

XV.—*Annagary.*—A feldspathic paste, with large crystals of orthoclase and fragments of quartz: contains also crystals of sphene, locally abundant (and occasional hornblende (?) in $\frac{1}{4}$ in. crystals). It is found beside the limestone, whenever the latter comes in contact with the granite, as at Annagary, Glenleheen, and Barnesbeg.

XVI. *Strontian, Argyllshire.*—This granite is somewhat like that of Ardara in appearance, and also like the black gneissose granite, which is found as a variety at Glen. It is medium-grained, and contains:—

(*a*). Quartz.
(*b*). Feldspar; white (oligoclase), having the characteristic striæ.
(*c*). Black mica; abundant.

XVII. *Tobermory, Mull.*—A coarse-grained granite, resembling the coarser varieties of the typical granite of Donegal. It contains—

(*a*). Quartz; abundant.
(*b*). Pink orthoclase; large crystals ($\frac{1}{2}$ in. by $\frac{1}{4}$ in.).
(*c*). White oligoclase; striated.
(*d*). Black mica; not abundant.
(*e*). Sphene facets; occasional.

The rocks whose analyses are contained in the above Table are hardly to be considered as all true granites. Nos. IV. and XIII. are rather to be considered gneiss than granite, and No. XV. is a feldspathic paste; but in the mode of their occurrence they do not differ from the granites, and it is impossible to say exactly where the granite begins and the gneiss ends.

TABLE VI.—*Chemical Composition of Donegal Syenites*.*

	Silica.	Alumina.	Iron, peroxide.	Iron, protoxide.	Lime.	Magnesia.	Soda.	Potash.	Manganese, protoxide.	Water.	Totals.
I. Lough Anure......	49·20	18·32	7·12	1·95	9·72	7·11	1·92	1·72	1·00	1·20	99·26
II. Kilrean, near Ardara	44·40	25·00	6·45	2·11	10·17	3·51	2·58	2·66	0·84	1·08	98·80
III. Doonan Hill	50·08	18·84	7·05	1·03	12·37	6·57	2·39	0·57	0·88	0·80	100·58
IV. Locality unknown	58·04	16·08	8·27	0·45	6·52	2·94	4·65	2·21	1·12	...	100·28

I. A medium-grained syenite or crystalline greenstone, composed of small plates of black mica with hornblende aggregated together, and of a feldspar which seems to be oligoclase.

II. A coarse-grained syenite, containing—

(*a*). Long crystals of green hornblende.
(*b*). White feldspar.
(*c*). Specks of iron-pyrites.

In addition to the composition given in the analysis, the rock contained 1·078 per cent. of sulphur, which no doubt was present in the form of pyrites.

* For a description of the relations of these rocks to the other rocks of the county, see p. 48 *et seq.*

III. A crystalline greasy trap rock, forming a dyke which penetrates the lower arenaceous Carboniferous limestone, and expands into a mass on the top of the hill, close to the town of Donegal. It contains black hornblende and a green feldspar.

IV. The analyses of the feldspar and hornblende of this rock have already been given. The precise locality of the specimen analyzed is unknown; but it resembles very closely the syenites of the Black Gap and Ballykillowen. It forms a link between the granites and the syenites. It contains—

(*a*). Quartz.
(*b*). Oligoclase of a pinkish-yellow colour; large crystals, brilliant cleavage.
(*c*). Hornblende, dark glossy blackish green, passing into black mica.
(*d*). Occasional crystals of sphene.

Determination of the Mineralogical Composition of the Donegal Granites.*

The determination of the mineralogical constitution of a granite is a problem whose solution has been frequently attempted; and at first sight it does not seem to present features of extraordinary difficulty. It may be stated as follows:—

Given the chemical composition of a rock and of its supposed constituent minerals, it is required to find the proportions in which these minerals are associated in it.

In the case which is now under our consideration, we assume that the four minerals, quartz, orthoclase, oligoclase, and black mica, all of which have been observed in the granite, are its constituents, and we take their chemical composition as ascertained by the analysis of specimens obtained exclusively within the county Donegal.

The principle of this investigation has already been published by Professor Haughton, in the paper already referred to (Quart. Journ. Geol. Soc. Lond. vol. xviii. p. 403), and its complete discussion will be laid by him before the Geological Society of London at an early date. It may, however, be of interest to lay before the Association the results at which he has arrived.

By the conditions of the question, we obtain four equations to determine the same number of unknown quantities, as will be seen by a reference to the paper. From the coefficients of the several quantities we obtain, by actual multiplication, the following ten constants:—

$$\begin{array}{lll}
\alpha = 69077. & \beta = -188220. & \gamma = 196703. \\
\alpha' = -113443. & \beta' = 211768. & \gamma' = 79167. \\
\alpha'' = 41702. & \beta'' = -\ 24442. & \gamma'' = -163140. \\
 & K = 34131692. &
\end{array}$$

Once these constants have been determined, nothing but simple multiplication and division is required, in order to ascertain at once with absolute certainty the percentage of each of the four minerals, whose analysis has been given, in the granite, *e. g.*:—

$$\text{Percentage of orthoclase} = 10000 \left\{ \frac{A\alpha + B\beta + C\gamma}{K} \right\}.$$

The results of the application of these constants to each of the seventeen granites whose analysis is contained in Table V. is given in Table VII.

* This portion of the Report is solely due to Professor Haughton.

TABLE VII.—*Mineralogical Composition of Donegal Granites.*

	Orthoclase.	Oligoclase.	Mica.	Quartz.
I.*	2·51	71·03	0·93	25·39
II.	122·87	−14·15	−8·33	−0·51
III.	−12·45	75·95	8·13	28·74
IV.	38·28	71·75	−2·01	−8·17
V.*	17·98	55·58	2·69	23·91
VI.	22·41	75·60	−10·28	12·76
VII.	36·13	52·38	−3·92	15·85
VIII.*	5·83	54·02	8·70	31·33
IX.*	25·45	41·50	2·74	30·30
X.*	16·48	46·31	2·05	35·36
XI.*	29·12	37·02	8·77	25·08
XII.*	29·45	48·07	1·69	20·78
XIII.	158·22	12·83	−29·48	−42·41
XIV.	−5·41	90·69	−15·02	29·46
XV.*	33·58	32·25	2·63	31·65
XVI.	125·94	47·96	−43·79	−29·14
XVII.	39·71	86·50	−19·87	−5·08

According to this Table, it appears that eight of the granites (those marked with an asterisk in the Table) give positive values for all the unknown quantities, while the remaining nine have one or more of them negative. Hence it follows that more than one-half of the granites in question are certainly *not* composed of the four minerals which have been assumed to be in them. In the case of eight of the granites it has been proved that they *might be* composed of four minerals, having the oxygen-ratios of those which have been analyzed; but it still remains to be proved whether they are so composed or not.

It is well known to be the opinion of many petrologists that it is unsafe to draw conclusions as to the constitution of a crystalline rock, like granite, from the analyses of crystals picked out from those portions of the rock which are coarse-grained enough to allow of such a process of extraction of minerals. Here we may be allowed to remark that if there be this doubt as to the validity of reasoning based on the analysis of minerals picked out of the very rock to which that reasoning is applied, it is *à fortiori* much more rash to call to our aid analyses of minerals from other localities, which have never been *proved* to exist in the district under examination, and the evidence of whose existence depends at best on the results of a microscopic examination.

In order to ascertain how far this suspicion is founded on truth in the case of the granites of Donegal, we must call to our aid the auxiliary equations which have not yet been employed. These depend on the iron, lime, soda, potash, &c., and have hitherto been grouped together in the equation containing the oxygen-ratio of the protoxides.

It is evident that, before we can say that a granite is really composed of the minerals whose composition has been given in the preceding part of the Report, we must be certain that all the equations of condition furnished by each constituent are fulfilled, as well as those depending on the oxygen-ratios of the protoxides, peroxides, and silica.

On applying these test equations, it is found that not a single one of the eight granites which have satisfied the first test fulfils these conditions accurately, and therefore that not a single granite of those which have been examined can be composed of quartz, orthoclase, oligoclase, and black mica having the precise composition which has been assumed for them.

The test is a very severe one, and in order to show the degree of approximation which has been attained by the method, we take the instance of the granite of Doochary Bridge, No. IX., and give the value of each constituent as calculated from the result given in Table VII., and as obtained by actual analysis of the rock.

Composition of Granite of Doochary Bridge.

	Observed.		Calculated.
Silica	72·24	....	72·24
Alumina	14·92	....	15·05
Iron and manganese oxides	2·18	....	1·52
Lime	1·68	....	2·91
Magnesia	0·36	....	0·48
Soda	3·51	....	2·89
Potash	5·10	....	4·90
	99·99		99·99

Hence we see that, although we may assume that a considerable proportion of the granites of Donegal are composed of the four minerals in question, yet the constitution of these minerals, when present in the mass of the rock, must differ slightly from that ascertained by the analysis of the larger crystals.

In conclusion, we may state that complete series of the minerals and rocks described in this Report are preserved in the Geological Museums of Trinity College, Dublin, and of the Royal Dublin Society, the actual specimens which were subjected to analysis being in the first-mentioned collection.

APPENDIX.

The following catalogue of localities has been compiled, partly from the published accounts of the tours undertaken by Sir Charles Gièsecke, in the years 1826–27, at the expense of the Royal Dublin Society, and partly from the results of the explorations carried out in the preparation of the preceding Report. Much valuable information has been derived from the gentlemen whose names have been already mentioned, and from an examination of specimens collected by the late R. Townsend, Esq., C.E., who resided in the county for some years.

The names of Messrs. Greg and Lettsom are given as authority for localities given in their 'Manual of Mineralogy,' which we cannot otherwise identify. We regret to say that much reliance cannot be placed on these localities, as they have not been personally identified by the authors of that work (see under *Analcime* and *Gypsum*).

All localities which have been identified by the British Association Committee, in the progress of their investigations, are marked with an asterisk.

CATALOGUE.

Simple Elements.

Graphite. Found in rolled pieces on the shore of Sheephaven, near Ards House; in the Burndale, Convoy; *in situ* at Fintown.

Sulphurets, &c.

Galena. Has been worked in several localities, the chief of which are Kildrum; Marfagh; Ards; Fintown; Drumnacross; Kilrean; Mullanti-

boyle; Welchtown; Malinbeg; Abbey Lands and Abbey Island, Ballyshannon; Ballymagrorty; Finner; Tonregee; Glentogher, Carndonagh; Castlegrove, Letterkenny. (Griffith's "Mining Localities of Ireland," Journ. Geol. Soc. Dub. vol. ix. p. 143.)

MOLYBDENITE. In hexagonal plates with actynolite, disseminated through elvan at Lough Laragh*, near Glenties; at Lough Anure.

Note.—Molybdenite also occurs in the oligoclase veins at Garvary*, near Castlecaldwell, two miles from the county of Donegal.

BLENDE. Occurs with galena at several of the localities mentioned for that species, especially Kilrean* and Fintown.

COPPER-PYRITES. Not very common; occurs crystallized at Kildrum.

IRON-PYRITES. Cubes of iron-pyrites are abundant in the mica-slate and accompanying rocks, in various parts of the county, particularly near Killybegs* and at Culdaff* and Malin. At Crohy Head* large crystals occur in the soapstone.

MAGNETIC PYRITES. Occurs in detached crystals in the metamorphic rocks about the Barnesmore Mountains, and at Leaght; at Doorin Rock*. The variety found at Barnesmore contains traces of nickel and cobalt.

FLUOR SPAR. Occurs in the limestone near Donegal; the variety is phosphorescent; at "the Pullans"; at Rathmullen.

OXIDES (METALLIC).

RUTILE. Prisms of this species occur in quartz-pebbles in the River Dale, and in mica-slate in Arranmore; at Malinbeg, large prisms in quartz (Greg and Lettsom); at Ards.

SAPPHIRE. A few rolled crystals were brought from the county of Donegal by R. Townsend, Esq., and given by him to Professor Apjohn. Precise locality not known.

MAGNETIC IRON. Octahedral crystals occur in the syenite at Horn Head*, and throughout the Dunfanaghy district. Also in serpentine at Aghadoey*, and in anthophyllite at Crohy Head*.

ILMENITE. Plates of this species, called rutile by Sir C. Gièsecke, occur in quartz at Woodland Dooish, near Stranorlar; and at Edergole, near Corabber Bridge, Lough Eask; at Breaghy Head.

SPECULAR IRON. At Glenkeeragh and Fox Hall.

MICACEOUS IRON. Near Malin*, and at Croaghonagh Quarry*, Lough Mourne.

RED HÆMATITE. At Innishkeel; pseudomorphous in cubes, replacing iron pyrites, at Woodland Dooish, near Stranorlar.

BROWN HÆMATITE. At Malinbeg, in a lode.

Bog Iron Ore.—Very abundant throughout the mica-slate district of the county.

PSILOMELANE. Impure psilomelane occurs in Arranmore and in the Slieve League district.

OXIDES OF SILICON, &c.

QUARTZ. *Rock Crystals.*—Leabgarrow*, Arranmore Island (very fine); Slieve League.

Rose Quartz.—Bradlieve Mountain, near Ballintra; in veins in granite, Pollakeeran Hill, near Lough Mourne; Maghery.

Amethyst.—In veins in granite, at the Waterfall in Barnes River*, half a mile above Barnes Lough, and on Edergole Mountain.

Smoke Quartz.—Very fine crystals, with graphic granite in a vein at

Brown's Hill*, Barnesmore Mountains; Slieve League; Barnesbeg Gap; Knockastoller.

CHALCEDONY. In rolled pieces at St. Peter's Lough, Mountcharles; in amygdaloidal trap at Doorin Rock*; Cloghan (Greg and Lettsom); Ards. Very abundant in micaceous conglomerate in the baronies of Raphoe and Innishowen.

OPAL. At Mountcharles.

SILICEOUS SAND. In great abundance, and extremely pure, on top of Muckish Mountain.

LYDIAN STONE. Common in the Carboniferous Limestone between Donegal and Ballyshannon.

ANHYDROUS SILICATES.

ANDALUSITE SECTION.

ANDALUSITE. In mica-slate, at Clooney Lough*, near Narin; on Scalp Mountain, four miles W.N.W. of Muff (Greg and Lettsom); at Barnesbeg Gap.

CHIASTOLITE. Barnesbeg Gap.

KYANITE. In mica-slate, with garnets, schorl, and sphene, in the reef of rock which runs from Fin M'Coul's Pan, Ballykillowen*, to Lough Derg; at Altnapaste; near Doocharry Bridge.

FIBROLITE. In gneiss, in several localities, where that rock occurs in the granite, Croaghnamaddy*, near Dunglow; Lough Anure*, at the north end; Annagary Hill*, behind the pound. The best crystals are at Lough Anure.

BERYL. In quartz veins and in granite, at Sheskinarone*, one mile north of Dunglow, on the road to Annagary.

Beryl occurs also, disseminated through the granite, at the same locality, in a subcrystalline condition, forming beryl granite.

TOURMALINE. *Schorl* is very abundant in the gneiss in the neighbourhood of Ballyshanon and Donegal, especially about Ballintra*, and at Knader; with garnets and kyanite at Ballykillowen* and Golard*, near Donegal; in garnet-rock at Aghadoey*; in granite at Annagary*; at Cloghan; at Kilmadoo, parish of Clondehorkey; and at Glinsk, in Fanad.

Indicolite.—Some dark-coloured prismatic crystals, from the county of Donegal, occurring in granite, and labelled augite, proved on examination by Dr. Aquila Smith to be indicolite.

SPHENE. Very abundant in granite throughout the county, especially in the white granite of Narin*, and Aphort*, Arranmore.

In gneiss, with kyanite, schorl, and garnets, at Ballykillowen*.

In a peculiar rock, consisting of orthoclase, green pyroxene, and quartz (sphene rock), which occurs in contact with the highly crystalline limestone of the granitic district of the country.

It is most abundant at Annagary*, where there are two types of sphene rock—one containing small crystals of sphene, with dark green prisms of pyroxene, the other containing sphene in larger crystals, and in much greater abundance, and in it the pyroxene is of a light green colour and less distinctly crystallized. Also at Barnesbeg* Gap, near Kilmacrenan, where large nests of sphene are found; in Glenleheen*; and in the neighbourhood of Lough Nambradden*, near Fintown; at Cloghercor, parish of Innishkeel; and at Tirlyn, near Creeshlagh.

AUGITE SECTION.

PYROXENE. Two varieties, coloured light and dark green, occur with orthoclase and quartz, forming sphene rock, at most of the localities where

limestone is found in the granite, *e. g.* Annagary*, Glenleheen*, and Barnesbeg*; Knockastoller and Derryloaghan.

Sahlite.—Occurs in quartz at Lough Nambradden, near Fintown; at Glenties.

Augite.—In prisms, imbedded in greenstone, at Tory Island.

Tremolite. Abundant in crystalline limestone, with idocrase and garnet, especially at Annagary* and Bunbeg*.

Anthophyllite. At Finmore; the Craigs, Raphoe; Crohy Head*, in the cliff, 200 yards from the eastern extremity of Aghnish Lough; at the mill near Gartan Abbey*, close to the soapstone.

Actynolite. In elvan, with molybdenite, at Lough Laragh, near Glenties*; at Gartan and Drumsallagh.

Asbestiform Actynolite.—At Tirlyn; Aghalative, near Ards; Glenaboghill; and Fintown.

Hornblende. Abundant in syenite throughout the county, especially at Loughrosmore; Horn Head*; at the Black Gap*, and in the townland of Golard*; Lough Anure.

Hornblende Rock.—Is found at Kilrean*, near Ardara; Raneany Bridge*, near Laghy.

Asbestus. At Kilrean, near Ardara*; at Crohy Head; at Rathmullen; in potstone, at Leaght, parish of Donaghmore.

Chondrodite. In crystalline dolomite near the Guidore (Greg and Lettsom).

Olivine.—In a trap-dyke at Drumnalifferny, parish of Gartan.

GARNET SECTION.

Garnet. Occurs disseminated through gneiss and mica-schist in the S.E. part of the county, especially at Golard* and Ballykillowen*, parish of Templecarne; at Aghadoey*, it occurs in the gneiss in such quantities as to form garnet-rock. Clear varieties occur in granite at Shallogan Bridge, and on the south side of the Guibarra valley; in the Poison Glen; at Tirlyn and Killoughcarran, near Creeshlagh; and in limestone at Aphort, Arranmore*.

Opake varieties occur, with hair-brown idocrase, epidote, and tremolite, in crystalline limestone in many places, *e. g.* Glenleheen*; Derryloaghan; Toberkeen*, near Dungloe; Annagary*; Lough Anure*; Bunbeg*; Barnesbeg Gap*, near Kilmacrenan; Tirlyn.

At Toberkeen, loose crystals, many of them pitted and worn by the action of the sea-water, are found on the beach. They are frequently 2 inches or more in diameter.

Cinnamon-stone.—At Trawenagh Bar.

Grossular.—At Annagary*; at Bunbeg.

Idocrase. The bacillar variety occurs in limestone at most of the localities above mentioned for opaque garnets; also at Madavagh, near Lettermacaward. On the promontory, at the north end of Lough Anure*, it is found in four-sided crystals; also at Toberkeen.

Epidote. Occurs pretty commonly, with garnet and idocrase, in the altered limestone. At Drumnaha, Glenleheen*, it is found well crystallized; at Aphort*, Arranmore, in great abundance; in gneiss close to the limestone at Pollnacally*; Crohy, in a vein in syenite; at Woodquarter, parish of Mevagh; at Muckamish and Rathmullen, parish of Killygarvan; at Lough Laragh, near Glenties.

Scapolite. In sphene rock at the Cross Roads, in Glenleheen*; at Tirlyn.

FELDSPAR SECTION.

ORTHOCLASE. Of a pinkish colour, very abundant in gneiss along the southern edge of the granite, about Lough Errig* and Glenleheen*; at Lough Barra; also in veins in the granite at other localities, especially at Pollnacally*, and near Lettermacaward; at Breaghy Head; white in Glenveagh*; at Knockastoller; crystallized specimens occur with the beryls at Sheaskin na Rone*, and also in the neighbourhood of Lough Nambraddan*, near Fintown.

In a quartz vein, with chlorite and micaceous iron, at Croaghonagh* Quarry, near Lough Mourne.

OLIGOCLASE. Abundant in granite, accompanying orthoclase, throughout the county, especially at Annagary*; in gneiss at Glen*, near Creeshlagh*; in syenite, at Black Gap*, near Pettigo, and at Ballykillowen*; at Knader, near Ballyshannon.

Note.—The veins of greenish oligoclase and black mica, containing molybdenite and copper-pyrites, which were discovered by the Rev. S. Haughton, occur at Garvary Wood, near Castlecaldwell, county of Fermanagh, about two miles from the border of the county Donegal.

LABRADORITE. Opalescent feldspar, supposed to be labradorite, occurs in boulders of granite in the Gweebarra valley, and along the shore of the Rosses.

Aventurine feldspar.—Was found by Sir C. Gièsecke in the Doochary district.

PITCHSTONE. Dykes of this rock, some of which are amygdaloidal, penetrate the granite of Barnesmore*, and are also found in other parts of the county.

FELSTONE. Felstone porphyry occurs in a columnar dyke in granite between Tordhu and Cladaghillie, in Arranmore*.

HALLOYSITE. At Drumsallagh.

MICA SECTION.

WHITE MICA. This occurs in considerable quantities in the granite, together with black mica. It is common at Sheaskin na Rone*, near Dunglow, with the beryls; also at Ballaghgeeha Gap*, Dooish Mountain; in gneiss (speckled) at Breesy Mountain*; at Madavagh, near Lettermacaward.

BLACK MICA. This occurs in small plates throughout the whole area of the granite, and also in the gneiss on its flanks, especially at Glen*, near Creeshlagh. It is also found in nests in the granite, as is the case at Newry; also in syenite and hornblende rock, but sparingly, at Kilrean*, near Ardara.

Large crystals are found in quartz at Annagary*; also at Ballaghgeeha Gap*, Dooish Mountain, and at Doochary Bridge.

Green Mica, produced by weathering from the foregoing, is found in a remarkable granite-vein which penetrates the gneiss near the Black Gap*; also radiated, on quartz, near Rockhill.

CHLORITE. In quartz at Malin*; with orthoclase and quartz at Lough Mourne*; at Killybegs*; Ards.

HYDROUS SILICATES.

TALC SECTION.

TALC. At Crohy Head*, crystallized, with iron pyrites; Foxhall; Glenkeeragh; at the Reelan Bridge.

SOAPSTONE. At Crohy Head*; at the mill, near Gartan Abbey*; at Ards; at Glinsk, in Ross Guill.

POTSTONE. Called "Cambstone" in the neighbourhood, at Convoy*; at Leaght, parish of Donaghmore; near Killygordon; at Culdaff*.

Serpentine. *Common serpentine*, with magnetic iron, occurs at Aghadoey*, near Donegal, close to the garnet rock; at Rossnakill*, in Fanad; near Dunfanaghy (Greg and Lettsom).

Noble serpentine.—Occurs near Drumbo.

Verde antique marble.—Occurs at Crohy Head*, near the coast-guard station.

ZEOLITE SECTION.

Natrolite. In the cavities of the amygdaloidal trap-dyke called Doorin Rock*, near Mountcharles; also in Barnesmore Mountain*, in pitchstone dykes; in trap-dykes at Lough Barra, and in the Poison Glen.

Analcime. In opaque crystals, with garnet and idocrase, near the Guidore (Greg and Lettsom) [?].

Carbonates, Sulphates, &c.

Calcite. At Cloghan; in the neighbourhood of Donegal, at Lacken and Laghy quarries (phosphorescent when heated).

Black.—At Rathmullen and Culdaff*.

Pink.—At Ards; at the Reelan Bridge.

Arragonite. In limestone at "the Pullans," near Brown Hall.

Marble, *white* (statuary marble), at several localities, especially Dunlewy*; Marble Hill*; Glenveagh*; Dunfanaghy*; Croaghanarget*, parish of Killymard.

Pink.—At Ards; at Muckish Mountain.

Sparry Iron. At Glentogher, Innishowen; at Tircallan, near Stranorlar.

Calamine. Near Ballyshannon.

Lead, Carbonate of. At Keeldrum mine.

Heavy Spar. Occurs as a gangue at Fintown*.

Gypsum. A quantity of fibrous gypsum is lying at Woodhill, Ardara, which is said to have been found by Major Nesbit, the late owner, on the property, about thirty years ago: no person is able to give any information about it. The locality given by Gregg and Lettsom, viz. Ballintemple Glen, parish of Errigal, appears to be incorrect, as Errigal parish is not in the county of Donegal.

Pyromorphite. At Keeldrum mine.

Apatite. In brownish-black mica near Annagary; in sphene rock at Barnesbeg.

Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge. By J. Gwyn Jeffreys, *F.R.S.*

Of all the objects connected with natural history which have been promoted by the Association, and which particularly engage the attention of a large class of its members, probably no one is more useful and interesting than the exploration of the British seas by means of the dredge. In a zoological point of view, such investigations are absolutely necessary for the study and elucidation of our marine fauna. Comparatively but few of the Invertebrata are met with on the shore or between tide-marks; the great bulk of them are found seawards. Every "zone," or bathymetrical district, has some characteristic or peculiar species of its own,—although these zones cannot be precisely defined, and many species inhabit more zones than one. Everything in nature is gradual, and merges one into the other. There are in

reality no sharp and abrupt lines in the picture, such as the inventive but partially instructed mind of man is apt to conceive when he frames what he considers a perfect system of classification. Marine animals do not seem to care so much whether there are five or five hundred fathoms of water over them, as whether they have a sufficient supply of food and the requisite shelter. It is extremely desirable to know more about the conditions of their habitability and the limits of depth within which each species can thrive or exist. In a geological point of view, the importance of this subject cannot be too highly estimated, especially as regards the last-mentioned subject of inquiry. At present we have no satisfactory information as to the depth of the primeval seas. It was at one time conjectured that the absence of colour was a test of depth; but it has now been ascertained that the most brilliant and variegated hues are not wanting in living creatures obtained from the abysses of the ocean. My friend Dr. Otto Torell informs me that during his last expedition to the Arctic seas, which was undertaken at the instance and cost of the Swedish Government, he found a large and undescribed kind of coral, on which were three live specimens of an *Actinia* of a bright red colour. The coral and its appendages were entangled in the machine which was sunk to the bottom of the sea. The depth was 1480 fathoms, being more than a mile and two-thirds in vertical measurement. Dr. Wallich has also given, in his valuable work 'The North-Atlantic Sea-bed,' a highly interesting account of the capture of living and full-grown star-fishes (*Ophiocoma granulata*), of a dusky-brown colour, at a depth of 1260 fathoms. It is beyond all doubt that the coral, sea-anemones, and starfishes actually lived on the sea-bottom whence they were taken, and that they had not been accidentally transported to the spot by any current, much less that any of them could have been swimming or floating, so as to become thus entangled in the sounding-apparatus or rope on its passage upwards through the water. Dr. Wallich has clearly refuted the objection, which was at one time made to his statement, that the star-fishes might either have been drifted to the position in which they were discovered by a superficial or deep-seated current, or else that they might have propelled themselves to it from some distant coast-line. The habits of these animals, and the nature of the organisms found in their digestive cavities, would render the latter proposition extremely improbable, if not impossible; while the direction of the only upper current which is known to flow in that course, and the conditions resulting from a lower current (if any such exists), would show that the phenomenon could not be explained in this way. In our own seas, and especially in that part which washes the coasts of Shetland, I have frequently dredged, at depths between 80 and 90 fathoms, living Mollusca whose shells were marked with stripes, bands, and spots of the most vivid colour; and these were of species which also inhabit shallow water on other parts of our coast, and which are often in the latter case colourless. *Pectunculus glycymeris* was here found to be variegated by rich streaks and zigzag blotches of reddish-brown; *Tellina pusilla* had bright rosy rays; *Psammobia costulata* exhibited delicate pink markings; *Trochus zizyphinus* had a uniform brick-red hue; and *Natica marochiensis* was spotted with purplish-brown. The animal of *Marginella lævis* also was beautifully painted, and displayed its gaudy tints of green, pink, and flake-white. Other geological problems of equal interest may be solved by the use of the dredge; and some of them will be presently noticed.

There is likewise another aspect in which these researches may be regarded in connexion with the British Association. The first object of the Association, as declared by its promoters and accepted as the basis of the institution, is

"to give a stronger impulse and a more systematic direction to scientific inquiry." This object is especially promoted by means of the votes granted for dredging on the British coasts. Such undertakings, if properly conducted, are very expensive, and tax heavily the private resources of members who pursue them on their own account and unaided. To make a short trip now and then in a small sailing- or rowing-boat, going out after breakfast and dredging for a few hours in the shallow bays on our southern and western coasts—the weather being fine, and the amateur dredgers not very sea-sick—is a very pleasant and inexpensive affair. To make an expedition to the most northern part of our seas in a steamer or good-sized sailing-vessel, occupying several weeks, for the purpose of exploring the open and deep sea at a distance of not less than twenty miles from the land—the weather being most capricious and often stormy—involves a considerable outlay and some personal risk, to say nothing of the preparatory work, or of the toil, discomfort, and anxiety which attend such an undertaking. In the latter case the naturalist is sometimes obliged to leave the shore (where he must have quarters in order to work out the results of his dredging) in the evening or at dead of night, when the wind generally lulls: he finds himself in the morning in the spot which he has marked for his operations; he has the dredges put out and all ready for action; the wind suddenly and without any warning rises, and increases from a stiff breeze to half a gale; it is useless to persevere, as the dredges will not lie on the bottom; and immediate return is unavoidable. If a sailing-vessel is employed, much time is lost in getting to the ground; and I have been cruising for eighteen hours in a smart and fast yacht before I could reach the desired spot, only 45 miles distant from the land. Sometimes a dead calm would ensue and last for two or three days together; it was impossible even to get out of harbour. Having experienced this difficulty on former occasions, I chartered this year a steamer from Scarborough, and proceeded to Aberdeen, where I was joined by Mr. Robert Dawson of Cruden, a most zealous and intelligent conchologist. We there attempted to dredge, remaining a week for that purpose; but the weather was too coarse, and the sea far too rough, to admit of our doing anything. At the end of that time we were joined by Mr. Edward Waller and the Rev. Alfred Merle Norman, both of them excellent naturalists, and the last well known by his numerous contributions to the study of our marine Invertebrata. From Aberdeen we all went straight to Shetland, and anchored in Balta Sound, Unst, which is the most remote of this northern group of islands. To indicate its whereabouts might be said by some to be a work of supererogation; but when it is recollected that Byron confounded the Orkneys with the Hebrides*, and that many otherwise well-informed persons have an indistinct idea that the Shetland Isles are either Scotch or else lie somewhere near Scotland, I trust I may be excused for saying a few words as to the position of these sea-girt isles that stud "the unadorned bosom of the deep." To show the comparatively high latitude in which Unst, the most northern of this group, is situate, I would observe that the lighthouse erected at its northern extremity lies in nearly 60°N., and within 7 degrees of the Arctic circle. It is 10 degrees north of the Scilly Isles. At Balta we were most kindly received and hospitably entertained by Dr. Edmonston (a name honoured in the annals of science) and by Mrs. Spence of Hammer. But we were again doomed to be baffled by the weather, and therefore we could not do as much as we had fondly anticipated. The results will be hereafter

* "The fair-hair'd offspring of the Hebrides,
Where roars the Pentland, with its whirling seas."
The Island, Canto 2.

shown. The expense of this expedition was about £300. It cannot be denied that the present case is one in aid and furtherance of which the funds of the Association may be properly applied. The grants amounted to £75; and the remainder of the expense was borne by myself and friends, including Mr. Leckenby, of Scarborough, who liberally contributed his money in the cause of science, although he was unfortunately prevented from personally assisting in the work of the expedition. The marketable value of all the objects of natural history which were procured by means of this expedition cannot be estimated at more than £5. It was purely a scientific inquiry; and the British Association gave a stronger impulse to it than if it had been undertaken by any naturalist for the mere sake of enriching his collection. The grant and prestige attached to it encouraged the Committee, and they endeavoured to the best of their ability to fulfil the charge with which they were entrusted. These grants supply to a certain extent the shortcomings of Government in respect of exploring-expeditions, such as used to be undertaken, and by means of which our present first-rate school of naturalists has been formed. Some fears must be confessed for the future. In the Belfast and Doggerbank dredging-excursions, which were liberally assisted by grants from this Association, many young and rising naturalists have been trained, and a taste inculcated for the study of marine zoology. Good fruit always follows good cultivation. I believe the Association has benefited in a pecuniary as well as scientific sense, by increasing the number of subscribers, and recruiting its ranks from local naturalists who take an interest in these pursuits.

The exploration of the Shetland seas has long been an object of mysterious and high ambition to British naturalists. In "An Account of some new and rare Marine British Shells and Animals," published in the 'Transactions of the Linnean Society' for 1811, Col. Montagu first described, as indigenous to our seas, *Terebratula cranium* (Müller), *Crania anomala* (Müller), and *Rissoa Zetlandica* (Montagu), all of which had been discovered on the south coast of Shetland by Dr. Fleming, when minister of Bressay. The two first-named species had previously been known only as inhabiting the Scandinavian seas; and the third was new to science. In 1828 Dr. Fleming published some more discoveries in his 'History of British Animals.' *Terebratula caput-serpentis* (Linné), *Spirialis Flemingii* (Forbes and Hanley), and *Scissurella crispata* (Fleming), besides several Nudibranchs, were the result of his further investigations. In the autumn of 1839 Professor Edward Forbes visited Lerwick, and did his usual good work, chiefly in the *Echinodermata* and *Acalephæ*, by dredging in the bays and fiords. The following extract from his note-book* will show his opinion of this district as a hunting-field:—"We have done very well, on the whole, in our visit to Shetland, especially considering how short our time has been. To add eleven or twelve new animals to the British fauna, and to see as many more exceedingly rare species, confined to this locality, is no small harvest for a naturalist to reap in a fortnight, especially when it is considered that six days of that fortnight were lost, in a manner, at sea." And then follows a characteristic *nota bene*:— "Must go back to Shetland." In 1841 I went to Lerwick, and dredged there, not being aware of Forbes having preceded me. Twenty-one species of testaceous Mollusca, none of which had been noticed by Fleming as Zetlandic, were the fruits of that excursion. *Thracia villosiuscula* (Macgillivray), *Rissoa rufilabrum* (Alder), and *Mangelia? nana* (Lovén) were added by me to the British fauna on that occasion. Forbes accompanied his friend Mr. M'Andrew,

* 'Life of Edward Forbes,' by Wilson and Geikie, p. 245.

in the year 1845, in a yachting voyage to the west coast of Shetland; and he was enabled to make another addition to the list, in *Trochus occidentalis* (Mighels and Adams), *Cerithiopsis metula* (Lovén), and *Aporrhais pes-carbonis* (Brongniart?). This excursion occupied some time. Besides the last-mentioned Mollusca, Forbes discovered many new species of *Medusa* and two new Echinoderms. In 1848 I again took my dredge to Lerwick, in order to complete a monograph on the British and Irish species of *Odostomia* for the Meeting of the Association held that year at Swansea. I found one more novelty in the way of Mollusca, viz. *Cylichna conulus* (S. Wood), which was then known only as a coralline-crag shell. My late friend, Mr. Barlee, went, at my suggestion, to Lerwick in 1857, and to the Whalsey or Outer Skerries, on the east coast of Shetland, in 1858, dredging for many weeks each year. I was by his means enabled to increase the list of indigenous Testacea by the goodly number of nine, viz. *Pecten aratus* (Gmelin), *Arca nodulosa* (Müller), *Poromya? subtrigona* (Jeffreys), *Skenea nitida* (Jeffreys), *Jeffreysia globularis* (Jeffreys), *Eulima stenostoma* (Jeffreys), *Odostomia minima* (Jeffreys), and a shell belonging to a new genus allied to *Trichotropis*, and which I provisionally named *Recluzia aperta*. A good yacht having been lent to me in 1861 by a relative, I revisited Shetland for the third time, being accompanied by my friends Waller and Norman. We took up our quarters at the Out-Skerries Lighthouse. In spite of storms and calms, we were tolerably successful; and I presented to the Association, at the Manchester Meeting in that year, a communication relative to the deep-sea dredging of Mollusca. Mr. Norman followed suit with regard to the Crustacea and Echinoderms. The Report for 1861 will testify to the amount of work done. Among the Mollusca were two quite new to science, viz. *Aclis Walleri* (Jeffreys) and *A. septemradiatus* (Jeffreys), and nine other species which had not before been found or noticed in our seas, viz. *Leda pernula* (Müller), *Neæra rostrata* (Chemnitz), *Cleodora pyramidata* (Eydoux and Souleyet), *Dentalium abyssorum* (Sars), *Margarita maculata* (Searles Wood), *Cerithiopsis costulata* (Möller), *Pleurotoma nivale* (Lovén), *Fusus Islandicus* (Chemnitz), and *Cylichna alba* (Brown). The *Cithara* is unusually interesting in a geological point of view. It is an undescribed fossil of the upper miocene, and has not been discovered in any newer formation. I lately detected two specimens (one adult and the other young) in the extensive collection of M. F. Cailliaud at Nantes from the "faluns" of Touraine; and he most obligingly presented them to me for the sake of comparison. I afterwards showed these specimens to the great palæontologist, Deshayes; but he was unacquainted with the species. Even the animal of the genus to which it belongs (*Cythara*, Schumacher) was previously unknown to science. With respect to the *Margarita* I may remark that the recent shell is of a pure and delicate pearl-white, with an iridescent gloss, and so unlike in appearance to the small and dingy fossil specimens found in the Coralline Crag that I had at first no suspicion that they were the same species, and I proposed to give to the recent shell the name of *elegantula*. The name of *maculata* is derived from ferruginous blotches which disfigure some of the fossil specimens. However, I am now satisfied that the Shetland specimens do not differ specifically from those of the Crag, and I must relinquish the name of *elegantula* in favour of the name given by its first discoverer, although the latter is exceedingly inappropriate and likely to mislead. The animal, as well as the shell, are exquisitely beautiful objects. Many novelties were also discovered among the Nudibranchs, Crustacea, Echinoderms, and Hydroid Polypes, for which I must refer to the valuable communications of Mr. Alder

and Mr. Norman. I could not resist the temptation of repeating my visit, last year, to the "ultima Thule" (if the ancients knew Shetland and called it by that name); and I was much pleased to have Professor Allman as my colleague. This time we stayed at Balta. The vessel I hired, although neat to the eye, turned out to be a poor and unseaworthy craft, and consequently was not of much use. We were greatly disappointed; and our dredging was cut short by the rudder-post being broken in a heavy sea. I succeeded, nevertheless, in procuring a live specimen of *Limopsis aurita* (Brocchi), only known before as a miocene fossil and from the Coralline Crag; and Mr. Waller detected in some of the dredged sand, which I sent to him for examination, two fresh valves of *Lima Sarsii* (Lovén), a new species of *Rissoa* (to which he proposes to give my name), and *Cleodora infundibulum* (S. Wood), the latter also a Coralline Crag species, and hitherto unnoticed as recent. This year were obtained two more species of Mollusca new to the British fauna, viz. *Arca obliqua* (Philippi) and *Scaphander librarius* (Lovén), besides four perfect specimens of *Limopsis aurita* (three of them living), three specimens of *Rissoa Jeffreysi*, the same number of *Cithara haliaëti* (one living), and a few very rare species, such as *Spirialis Macandrei* and *Axinus Croulinensis.* Two species (*Aclis unica* and *Odostomia cylindrica*), which had been considered southern forms, occurred for the first time in these northern latitudes. I had likewise an opportunity of confirming and extending some observations which I had made on former occasions as to the nature of the sea-bottom and bathymetrical conditions, as well as with respect to the bearing of these dredging-operations on certain geological phenomena.

The detailed result of all the explorations during the last few years in the Shetland seas, so far as they relate to the Mollusca, will be stated at the end of this Report. The first Table contains a list of species which I have added from this source to the British fauna since the publication of Forbes and Hanley's work. They are twenty-two in number. The second gives only a single species, which is as yet unknown elsewhere, either as recent or fossil. The third comprises the species (seven in number) which are unknown elsewhere, except in a fossil state; and the fourth such as are confined to this part of the British seas, being twenty-three in number. All these last-mentioned species are Scandinavian—a result which might have been expected from the geographical situation of the dredging-ground. The distance between the Whalsey or Out-Skerries and the opposite coasts of Norway is scarcely 150 miles; and this is reduced by from 20 to 50 miles where the dredgings were mostly carried on.

Besides the Mollusca, some of the rarest and finest Echinoderms (e. g. *Astrophyton Linkii, Echinarachnus placenta,* and *Cidaris papillosa*) are only to be found as British in this part of our seas. Mr. Spence Bate and Mr. Norman have described from this source several new Crustacea, Mr. Alder some Nudibranchs and Zoophytes, and Professor Busk species of Polyzoa which had been previously considered as belonging only to the Coralline Crag; and Mr. Brady has noticed a great many forms or species of Foraminifera heretofore said to be peculiar to the chalk and tertiary strata.

Beyond twenty miles seaward of Unst the tides are scarcely, if at all, felt; and the dredgings afforded no evidence of any marine current. In calm weather, the rope when hauled up was perpendicular, or (as sailors call it) "straight up and down." The depth was about 85 fathoms, and it varied but little for several miles further out to sea or in a parallel line. Here and for many square leagues north, east, and west there seems to be a still or quiescent region at the bottom of the ocean, unaffected by the storms which

so often vex the surface. From this part of the sea-bed were often brought up loose boulders, stones, and pebbles, of various sizes; some of them were rounded, and others angular, but all more or less covered with Zoophytes. Some of the so-called corals attached to these stones were exceedingly fragile and delicate; and if the sea-bottom from which they were taken had been subject to the action of tides or currents, however feeble, the corals would assuredly be broken to pieces by the stones being rolled and coming into contact with each other. Even the underside of the smallest pebbles was usually encrusted with exquisitely fine living Polyzoa, which had not suffered any injury by lying loose on the ground. But, of course, the sea at such depths never stagnates; it has a constant and free circulation throughout, and a ceaseless interchange of particles. In this region now live the species previously known only in a fossil state and occurring in the middle and upper tertiary strata, and which might therefore be supposed to have become extinct on the advent of the glacial epoch. Considering the vast extent of sea-bottom which has never been touched by the dredge, the exceedingly limited space measured in square acres which can be explored by means of it, and the infinite variety of ground comprised within any given area, I would suggest that great caution should be used, and further inquiries made, before the common expression is hazarded that certain species are now "dying out," whether slowly, gradually, or rapidly. I do not believe that such is the case. The fact of finding only dead shells in a particular spot is no proof that living ones cannot be met with in the same district. There may be, and often is, an accumulation of dead shells in one place, like bones in a grave-yard, in consequence of the shell-fish having deserted it for some reason with which we are not acquainted, while the living brood migrates or shifts its quarters. The proportion of dead to living specimens, even of common species which are not supposed to be "dying out," is often remarkable. Among many hundred single valves of *Lima subauriculata* which were this year dredged in Shetland, there was only one live specimen. *Scalaria Turtoni* has lately been dredged in considerable numbers off the Yorkshire coast; but all the specimens were dead. No one has yet found a live *Adeorbis subcarinatus*, although it is by no means uncommon in the greater part of the European seas. The late Professor Forbes described, in his admirable contribution to the Memoirs of the Geological Survey for 1846, what he called "a boreal outlier," or isolated assemblage of northern shells, which he found while dredging with Mr. M'Andrew in the deeps of Loch Fyne. He said, "The dead Mollusks taken were *Abra Boysii*, a species of similar range with *Nucula nucleus*; *Cardium Lovéni*, a Scandinavian species; and *Pecten Danicus*, a Norwegian species found only in the British seas, in the lochs of the Clyde, and then rarely alive, though dead shells are abundant, *as if the species* thus isolated were *now dying out*." Having had peculiar opportunities of studying the geographical distribution of the British Mollusca, I may mention that the species first named (*Abra Boysii*, or *Scrobicularia alba*) inhabits the Mediterranean, as well as the western coast of France; *Cardium Lovéni*, or *C. Suecicum*, is identical with *C. minimum* of Philippi, and is also a Mediterranean species; and *Pecten Danicus* (or *P. septemradiatus*, alias *P. adspersus*) has an equally southern range, although it is known in France and Italy by names differing from those which have been given to the same species in the north. *P. septemradiatus* is taken alive in considerable numbers by the fishermen in Loch Fyne, during the herring-season. Mr. Barlee obtained from them, ten years ago, two or three hundred perfect specimens during a short stay at Inverary; the principal shell-dealers continually receive supplies of this

pretty shell, and the stock seems to be inexhaustible. Mr. Norman reminds me of *Pomatoceros arietinus*, *Caryophyllia clavus*, *Comatula Sarsii*, and *Echinus Norvegicus* as occurring under similar conditions. I am confident that if my distinguished friend were now alive, he would candidly acknowledge that his first impression had not been confirmed, or at least that it was modified by subsequent observations.

No species appears to be confined to any limited district, although it may be locally distributed. The circumstance of its not having been found elsewhere is by no means a satisfactory proof that it does not exist beyond the supposed boundary. The more the bottom of the sea is explored, the greater will be the known extent of distribution. Instances in support of this proposition are so numerous that it is hardly necessary to adduce them. Among the bivalves, *Lepton squamosum*, and among the univalves, *Rissoa abyssicola*, may be cited as examples. Both of them were at one time said to be peculiar to our seas; but it has now been ascertained that they have a wide range, north as well as south of Great Britain, in other parts of the Atlantic Ocean.

The sea-bed is often greatly diversified within the same district, both as regards its shape and composition. Whenever the vessel was of sufficient size, I have had two dredges put out at the same time; so that directly one has been taken up the other is being hauled in. It has more than once happened that the contents of the second dredge were quite different from those of the first, the one consisting of shell-sand and the other of stones, or *vice versâ*. The depth of water remained the same. This change of ground must have taken place in the interval of a few minutes, when the first dredge was being taken up, and during which the vessel could not have drifted more than a couple of hundred yards. The vessel's head is always kept nearly to windward while she is dredging, so that she may not have too much way. A mile an hour is reckoned quite fast enough to keep her steadily at work.

Vast numbers of *Globigerinæ* abound everywhere in the dredged shell-sand. Dr. Wallich says *, "It is evident that there is an intimate association between the *Globigerina*-deposits and the Gulf-stream; for wherever we trace the one sweeping across the surface of the ocean, we are almost sure to detect the other resting on the sea-bed; and when we fail to trace the one, we almost as surely fail to detect the other." But it does not appear that the Gulf-stream impinges on the northern or eastern coasts of Shetland. No seeds, no *Ianthinæ*, *Velellæ*, or driftwood from the tropics have ever been picked up on these shores. On the contrary, the only driftwood which is here found floating or cast ashore consists of pine-trees from Norway—sometimes with their roots, and usually drilled by *Teredo nana*, being the same species that attacks fixed and submerged wood or boats lying long at anchor on the Shetland and Scandinavian coasts. Wood is too scarce and valuable a commodity in the treeless isles of Shetland to be disregarded by the natives. A Norway log is one of their chief prizes. It would seem from the foregoing facts that the *Globigerina*-deposits are generally distributed over the floor of the deep sea throughout a very extensive tract, irrespective of the course of the Gulf-stream.

Occasionally a little world of living animals is seen to occupy a single dead shell. An instance of such a microcosm was observed on a specimen of *Buccinopsis Dalei*, var. *eburnea*. Far within the shell an Annelid took up its abode. This may have been the first occupant after the true inhabitant had been cleared out, and it probably assisted in the evacuation. A Hermit

* The North Atlantic Sea-bed, p. 137.

Crab (*Pagurus Prideauxii*) kept possession of the body or last whorl; and a Sea-anemone (*Adamsia palliata*) enveloped the whole surface of the shell with its slimy mass. This group of various animals formed "a happy family," and did not seem to interfere in the least with one another.

There is good reason to believe that the sea-bed in this district has sunk considerably since the close of the glacial epoch. Single valves of *Rhynchonella psittacea*, *Pecten Islandicus*, *Astarte borealis* (or *arctica*), *Tellina calcarea* (or *proxima*), and *Mya truncata*, var. *Uddevallensis*, as well as dead shells of *Trophon clathratus* (or *scalariformis*), are occasionally brought up by the dredge from depths of between 75 and 85 fathoms, and in various parts of our northern sea. All the specimens have an unmistakeably fossilized or dull appearance, compared with that which distinguishes dead shells of other species still existing in the same locality. They are very different in that respect from the shells of *Columbella Holböllii*, and other species dredged off the coast of Antrim but not alive. These last are quite fresh-looking, and may never have been exposed to the air or parted with the animal matter which permeates the shell. None of the species first enumerated have ever been found in a living or recent state in the British seas. All are essentially Arctic forms. Their usual habitat is in rather shallow water; and the variety of *Mya truncata* lives between tide-marks. Other species of Mollusca, which are common in our seas, and inhabit the sublittoral or laminarian zone on the southern coasts, are found only in deep water off the Shetland Isles. Such are *Lamellaria perspicua*, *Nassa incrassata*, and *Cypræa Europæa*. Not one of these last is an Arctic form. I have already noticed the peculiarity of their occurrence at the above-mentioned depths, in the Report which I had the honour to present to the Association in 1861, and I ventured to express an opinion that it was owing to this part of our northern sea-bed having sunk within a comparatively recent period. Dr. Wallich has since confirmed this impression on my part by his history of the "sunken land of Buss," in the North Atlantic, not far from which supposed tract he found several specimens of *Ophiocoma granulata* living at the enormous depth of 1260 fathoms, the same species inhabiting on the opposite coast of Iceland from 10 to 20 fathoms only. Now, inasmuch as *Pecten Islandicus* and the other Arctic species above named are large and conspicuous forms, as well as gregarious in the places where they are now found, the question naturally arises, "Why has not a single living individual ever been discovered in that part of the British sea where the dead shells are not uncommon, although it has been sufficiently explored?" It cannot be said that they have died out, or become extinct, in consequence of the water having become of a higher temperature than it was during the period when they formerly inhabited the same part of the sea, or because some other conditions, unfavourable to their existence, have supervened. We have no proof or reason to believe that the temperature of the sea at a depth exceeding 75 fathoms has been at any time since that period different from what it is at present. Very many species of Mollusca, which are natives of the Polar sea, are also inhabitants of our coasts, where they apparently have not suffered the least diminution in number or vigour, although they may have dwindled in size. Several of the peculiarly Arctic forms above referred to, and which no longer live in the British seas, continue to exist in a parallel latitude on the coast of Norway; and two of them (*Astarte borealis* and *Tellina calcarea*) survive in Kiel Bay, more than 5° south of Unst, at a depth not exceeding 25 fathoms. I therefore can only account for this apparent extermination in our seas of the six species in question by suggesting that the

bed which they once inhabited was raised and became dry land; that it remained in that state for a period sufficiently long not only to destroy the entire brood, but also to semifossilize the shells by exposure to the action of the open air; that subsequently the tract was submerged, and again formed the sea-bed; and that it is still sinking by slow and perhaps imperceptible degrees. In this way the shallow-water species, as *Nassa incrassata*, would be gradually habituated to greater and greater depths, like the North Atlantic Starfishes.

Living Mollusca, procured from a depth of 75 fathoms and upwards, being placed in a shallow vessel of sea-water taken from the beach, did not seem to be in the slightest degree affected by the sudden change of bathymetrical conditions. With a solitary exception (that of *Cithara haliaëti*), all continued for a long time vigorous and active. They fed, crawled, leapt, and swam or floated immediately below the surface of the water in an inverted position. One pair of *Marginella lævis* was actually engaged for several hours together in celebrating the rites of "alma Venus"! It was not necessary to renew often the supply of water in order to ensure this state of liveliness. I kept many of them, and observed their habits, for three days, when they were killed for the sake of their shells.

I consider all marine beds, of comparatively recent formation, to be necessarily fossiliferous, assuming that the same causes which now exist were in operation during that period. Even if these beds do not contain the shells of Mollusca, the remains of other animals, or certainly some microscopic organisms (such as Foraminifera and Diatoms), can be detected by a careful examination. I am aware that this opinion is opposed to that of some able geologists. Mr. Geikie says, in his recent treatise 'On the Phenomena of the Glacial Drift of Scotland' (p. 126), "I believe the greater part of this drift, though it is unfossiliferous, to be of marine origin. Its occurrence on water-sheds or on the sides of mountains and hills far out of the reach of any stream seems sufficient evidence that in such cases fluviatile action must have been impossible. And in these situations the mounds of sand and gravel are exactly comparable with others which occur in lower parts of the country. It is difficult, therefore, to avoid regarding the whole as due to the operation of some one general agency. This agency was, in all likelihood, the waters of the ocean." The non-existence of fluviatile action in the places above referred to, at the time when the so-called drift was deposited, does not seem to me proved, taking into consideration the changes of level which may have since taken place. In certain inlets or arms of the sea, rivers flowing into them may have a sufficient velocity to sweep the middle of the channel, and prevent the deposit of any mud or sediment which would shelter certain animals. Indeed the continual action of the current might preclude the possibility of any animal living within the prohibited area; and in that case the central bed of the channel might be partly covered with clear sand, devoid of any organized structure. An illustration of this phenomenon will be found in Dr. Wallich's account of Hamilton's Inlet, Labrador. But such cases are rare, if not exceptional; and not only are the limits of such lifeless areas very circumscribed, but the absence of marine organisms may be attributable to the destructive property of fresh water. Many kinds of animals are known to exist and flourish in the most rapid tideways and even in whirlpools; and the water of the ocean everywhere teems with life. The dredge has never yet failed to bring up organic remains from every part of the sea-bed which has been explored, however unpromising it may appear to the naturalist. Even in the cleanest-looking

sand, taken from any spot beyond the reach of fluviatile action, some marine débris may be found. Having these facts and some experience to guide us in the inquiry, I think we ought not to call any strata which are unfossiliferous marine, unless there are sufficient grounds for supposing that the absence of fossils is caused by chemical absorption or decomposition.

The subjoined Appendix will show the additions made to the list of British Mollusca in consequence of the Shetland dredgings.

Mr. Norman and Mr. Brady will give in subsequent papers the results as regards other departments of the marine Invertebrata; and we hope to complete and publish next year a full catalogue of all the species.

I submitted to the inspection of Mr. Prestwich a sample of small gravel dredged up from 85 fathoms, and about 25 miles off Unst; and that eminent geologist has favoured me with the report which will be also found appended to this communication. One of these specimens deserves especial notice. It is a piece of conglomerate, composed of granitic and other fragments cemented by carbonate of lime. There is no calcareous rock within a considerable distance from the spot where this piece of conglomerate was found. It may be doubted whether the cement could have arisen from the re-solution of dead shells. The probability is that the specimen in question may have been carried during the glacial epoch by an iceberg or coast-ice from Norway. I have a large mass of conglomerate, composed principally of recent shells of a southern form, which was dredged between Jersey and the opposite coast of France; but this may have been formed by a submarine spring, charged either with carbonate of lime derived from the underlying chalk, or with carbonic acid sufficiently strong to dissolve any calcareous matter within the range of its action. The shells contained in the last-mentioned piece of conglomerate have not undergone any dissolution. I agree with Dr. Wallich as to the probability that "the demand for carbonate of lime at the bottom of the sea is limited only by the supply," and that there is no evidence of supersaturation as regards a material so essential to the construction of shells and similar organisms. For the elucidation of such minor problems as this we invite the attention of chemists and geologists.

APPENDIX.

Mollusca.

1. *Species found in Shetland, and added to the list since the publication of Forbes and Hanley's work.*

Pecten aratus, *Gmelin.* (P. sulcatus, *Müll.*)
Lima Sarsii, *Lovén.*
Leda pernula, *Müller.*
Limopsis aurita, *Brocchi.*
Arca nodulosa, *Müller.*
A. obliqua, *Philippi.* (A. Korenii, *Danielssen.*)
Neæra rostrata, *Chemnitz.*
Cleodora infundibulum, *S. Wood.*
C. pyramidata, *Eydoux* and *Souleyet.*
Dentalium abyssorum, *Sars.*
Margarita maculata, *S. Wood.* (M. elegantula, *Jeffreys, MS.*)
Rissoa Jeffreysi, *Waller.*
Odostomia minima, *Jeffreys.*
Aclis Walleri, *Jeffreys, MS.*
Eulima stenostoma, *Jeffreys.*
Cerithiopsis costulata, *Möller.* (Cerithium niveum, *Jeffreys.*)
—— ? aperta, *Jeffreys* (as Recluzia aperta).
Pleurostoma nivale, *Lovén.*
Cithara haliaëti, *Jeffreys, MS.*
Fusus Islandicus, *Chemnitz.*
Scaphander librarius, *Lovén.*
Cylichna alba, *Brown.* (C. triticea, *Couthouy.*)

2. *Species unknown elsewhere, either as recent or fossil.*

Jeffreysia globularis, *Jeffreys.*

3. *Species unknown elsewhere, except as fossil.*

Limopsis aurita. Miocene and Pliocene.
Cleodora infundibulum. Coralline Crag.
Margarita maculata. Coralline Crag.
Skenea nitida, *Philippi.* (S. lævis, *Forbes* and *Hanley.*) Sicilian Tertiaries.
Odostomia minima. Coralline Crag.
Aporrhais pes-carbonis, *Brongniart?* Miocene.
Cylichna conulus, *S. Wood.* Coralline Crag.

4. *Species confined to this part of the British seas, but also Scandinavian.*

Terebratula cranium, *Müller.*
Pecten aratus.
Lima Sarsii.
Leda pernula.
Arca nodulosa.
A. obliqua (Sicilian).
Neæra rostrata (Mediterranean).
Cleodora pyramidata (North Atlantic).
Chiton albus, *Linné.*
Dentalium abyssorum.
Scissurella crispata, *Fleming.*
Rissoa Jeffreysi.
Odostomia ? eximia.
Aclis Walleri.
Eulima stenostoma.
Cerithiopsis costulata,
C. metula, *Lovén.*
C. ? aperta.
Pleurotoma nivalis.
Cithara haliaëti.
Fusus Islandicus.
Scaphander librarius.
Cylichna alba.

5. *Description of small rock-fragments or gravel dredged up from 85 fathoms off the north coast of Shetland.*

4 fragments of white quartz-pebbles.
2 angular fragments of white (vein) quartz.
2 subangular fragments of dark grey quartzite.
1 subangular fragment of light brown calcareous sandstone.
2 subangular fragments of brown micaceous sandstone, slightly calcareous.
1 subangular fragment of argillaceous black limestone.
4 angular fragments of hornblende rock.
1 subangular fragment of red syenite.
2 angular fragments of red syenite.
3 angular fragments of light red granite.
2 pebbles of light red granite.
1 subangular fragment of red pygmatite.
2 subangular fragments of light red quartzose sandstone.
1 subangular fragment of white quartzose sandstone.
2 subangular fragments of red porphyry.
2 angular fragments of light-coloured granite.
1 subangular fragment of dark red porphyry.
1 angular fragment of grey quartzite.
1 small pebble of grey granite.
1 fragment of pebble of hornblende rock.
1 fragment of conglomerate, composed of the above materials, with a calcareous cement.

N.B. Mr. Prestwich remarks that these rock-fragments are so small that it is possible, or rather probable, that the fragments designated "pygmatite," "porphyry," and "hornblende" may in fact all belong to one granite rock. He is of opinion that the cement of the conglomerate may be derived from the calcareous matter of shells or Bryozoa.

Report on the Physiological Effects of the Bromide of Ammonium. By George D. Gibb, *M.D., M.A., F.G.S., F.A.S., Physician to the West London Hospital, and Assistant-Physician and Medical Registrar to the Westminster Hospital, London.*

Bromine and its salts have been known for many years to possess considerable virtues, and some remarkable instances of their peculiar effects, physiological and medical, have been placed upon record. Amongst others, the power of absorbing hypertrophied structure has been observed, especially enlargements of the spleen and liver, lymphatic glands, and scirrhous growths.

In an excellent essay by Dr. R. M. Glover (at one time a resident in Newcastle and afterwards in London), published in the Edin. Med. and Surg. Journ. for October 1842, there is a list of the diseases in which either bromine or some one of its preparations has been employed, but amongst the latter the bromide of ammonium is not mentioned.

The salt hitherto, it may be said almost solely, in use has been the bromide of potassium, considered by many physiologists analogous in its effects to the iodide of the same base, only that it is slower in its action. The persons whose names are deserving of mention in relation to the potassium salt, are the late Dr. T. Williams of London, who found it of great benefit in enlarged spleen; Pourché, who treated bronchocele and scrofula with success; and in a number of cases of pseudo-membranous disease, including a few of croup, M. Ozanam found it of especial value. Cancer is another disease successfully treated with it by Mr. Spencer Wells, in doses of five to ten grains three times a day, with cod-liver oil (Med. Times, July 1857, p. 31).

In the course of its use M. Huette observed that *anæsthesia of the fauces* was a result which its administration caused; and this circumstance, at first looked upon as objectionable, I have endeavoured to turn to account, as a physiological result of extreme value and importance in the practice of medicine, either in examinations of the throat and nostrils, or for the performance of operations upon either, or in the interior of the windpipe from above, by means of the laryngeal mirror.

To effect this object the bromide of potassium was freely given internally in large doses, but it failed to bring about this result, unless in a very few instances, its action varying according to the idiosyncrasy possessed by the individuals experimented upon. Its local action, although perhaps a little more certain and decided, was not to be relied upon.

On looking through the other salts of bromine, none seemed likely to possess more of the anæsthetic power than that of potassium; having had some experience, nevertheless, of the reliable value of the preparation known as the iodide of ammonium, it struck me that the analogous substance (bromide of ammonium) might prove more efficacious than the potassium salt, from the union of bromine with a base of great power, ready absorption, exerting a decided influence upon the fluidity of the blood, and moreover the remedy for poisoning by bromine, as recommended by Mr. Alfred Smee, namely ammonium. I was not aware at the time that it was employed for photographic purposes, probably more or less impure, but had the salt carefully prepared for my experiments by Messrs. Fincham of Baker Street, London.

The bromide of ammonium when pure is perfectly white and amorphous, with a feeble odour of sea-weeds. Under the microscope the salt is clear and transparent, and not crystalline nor deliquescent. It can, however, be crystallized in cakes or quadrangular prisms. It possesses a slightly pungent saline taste, not so sharp as that of common salt, nor so acrid as the bromide of potassium.

Agreeably to the request of the General Committee, I have performed a large number of experiments since bringing the subject before the Association last year at Cambridge, but the present Report combines the whole of the more important of my experiments from the first use of the salt, and from which are deduced its physiological and therapeutical properties.

In pursuing this inquiry, the salt has been administered in small doses at intervals more or less long-continued, in large doses frequently repeated or given at intervals, and in single daily doses. A comparison is also instituted

between the relative effects of this salt and the bromide of potassium. It may be mentioned that in these different experiments healthy persons were selected; and according to the results obtained, so were certain diseases submitted to treatment to more fully bear out and confirm the physiological effects noticed.

Effects of small Doses.—About one hundred healthy persons, male and female, of various ages, were given small doses of the salt, ranging from one to five grains, three times or more a day, in water as a vehicle, and in some combined with a simple colouring agent, such as the tincture of alkanet root or other substance. The period of its continuance varied from three weeks to several months, and the results were carefully noted. All were in tolerably good health, or nearly so; or if affected with any particular ailment, it did not appear to be likely to interfere with the action of the drug.

Two striking results were soon noticed in the greater number; namely, increase in the power of the appetite, and improvement of the complexion. With regard to the former, its action was that of a decided tonic; for whilst the persons ate more food than had been their custom, they were able to digest it well; the drug appeared to impart a soothing and comfortable sensation. There never was any tormina nor the slightest tendency to intestinal relaxation; but the general functions appeared to be regularly and consistently performed. The tongue assumed a natural and clean appearance, and was moist; the skin and mucous membrane (presently to be noticed) performed their functions well; the circulation was not increased nor lessened; the heart's action continued regular, the pulse possessing good power and volume, and comfort was experienced after meals. If there were indications of indigestion or dyspepsia before the use of the salt, they yielded to the small doses given. In six or seven cases, a mild diuretic effect was observed.

If the small doses were continued for some time these effects were not always continuous, and in a few persons slight nausea was produced, with an impairment of the appetite; this was especially so if the drug was given in four- or five-grain doses. In three cases only was there a little headache, with giddiness and light-headedness, but the intellectual faculties were unimpaired.

Coincident with the increase of appetite was a marked clearing of the complexion, particularly observable if the face was naturally florid or the skin very red. This redness or floridity became paler, decidedly paler, and the skin assumed a fine transparent freshness, indicative of healthy function.

Dinginess, slight sallowness, or a heightened complexion became modified or altered, so that a more healthy, slightly pink colour was assumed. These effects were noticed sometimes when the salt had been taken but a few days; and the improvement in the skin was so apparent, that it has attracted the notice of the friends of the persons under experiment.

Applying this result pathologically, I found the salt very serviceable in a variety of cutaneous affections, the eruptions fading away reasonably fast, and the individuals looking as clean and as clear about the complexion as if they had just come out of a bath. The results were very striking, and positively beneficial upon the skin. They are produced also by the other salts of bromine, but perhaps not in the same degree; I therefore feel justified in denominating the bromide of ammonium, amongst its other properties, as a beautifier of the complexion and cleanser of the skin. It appears to act by gently stimulating the capillaries of both the skin and mucous membrane; and secretion is excited in both by small doses of the salt, independently of exercise and increased diet.

Local and Constitutional Effects on the Mucous Membrane.—If the mucous membrane of the mouth and throat has been dry, or secreted less than natural, a healthy moisture is produced by small doses internally, which has proved very agreeable. In an instance wherein the taste was blunted and impaired, so that the sapid character of the solution employed locally was not noticed, it almost immediately improved, and became more sensitive to impressions. This is known to be the reverse with salts of iodine, which often produce a disagreeably bitter taste, pervading in some instances almost everything swallowed.

Although it will improve sensation in small doses or single applications, its essential property is exerted upon the sensation of the minute nerves of the mucous membrane of the soft palate and pharynx, the former especially. When locally applied, dissolved in water, or glycerine and water, a remarkably tranquil soothing influence is brought about, which continues for a certain period of time, and then passes off.

If the strength of the solution is increased, the perhaps heretofore dry membrane has its follicles stimulated; and whilst secretion is increased, sensation is somewhat diminished; but this last property varies in different individuals. If now topical application be resorted to through the aid of a tolerably strong solution of the salt, say from two to eight drachms, or even more, in six ounces of water, used either as a gargle or a paint every half-hour, the throat will become in a condition of mild local anæsthesia, that is to say, loss of sensation confined to the fauces, which will be more or less complete according to the susceptibilities of the individual and the period during which the solution is employed. I have seen it occur from the first to the ninth day; and the continuance of the anæsthesia will afterwards depend upon the amount of the salt locally absorbed, but generally diminishing after the first twenty-four hours, and not unfrequently continuing as long as three days.

Knowing that this anæsthetic property was attributed to the bromide of potassium by M. Huette, and applied by M. Gosselin in staphyloraphy*, I was prepared for its occurrence with the salt of ammonium, but the result of my experiments warrant me in saying that, whilst the anæsthesia is more complete and certain, it produces less inconvenience in relation to the sense of taste than does the bromide of potassium. The importance of this anæsthetic property cannot indeed be over-estimated in its application to a number of subjects connected with the throat especially, as modifying degrees of natural irritability, pain, sensation, secretion, mobility, and absorption.

Effects of large Doses.—It may be as well to mention here that the experiments of M. Huette with the sister salt, the bromide of potassium, went to show that headache was sometimes observed on the third day, but ordinarily occurred from the fourth to the seventh day, when the daily dose of the salt had reached from two to five drachms †.

According to its continuance in large doses, so were produced torpor and drowsiness, lowering of the pulse (40 to 48), vomiting and continued sleep, and finally a form of peculiar intoxication, characterized by impaired sight and hearing, utter helplessness and insensibility. Weakness of the mind and torpor of the genitals were other effects noticed. Among the special effects of the salt, one of the most remarkable, even from a feeble dose, observes M. Huette, is profound insensibility of the velum and pharynx, which persists throughout the duration of the treatment. How far the bromide of ammo-

* Gazette Médicale, April 14, 1860, p. 223.

† Annuaire de Thérapeutique, 1851, p. 216.

nium resembles the potassium salt, the following experiments will determine. Huette's experiments with the latter show well its influence upon various parts of the mucous tract, although he says nothing about the skin; M. Rames, however, observed an instance wherein the skin was so completely insensible that its puncture with a needle was not felt, and tickling of the conjunctiva or fauces with a feather produced neither winking nor desire to vomit*.

It was soon apparent in my own experiments with the bromide of ammonium that the entire mucous tract could be greatly influenced for good or for evil, according to the desire of the physiologist. And yet with proper care and judgment, we are furnished with an agent in this salt that promises to be of immense benefit to suffering humanity in many obscure and heretofore intractable diseases.

Experiment 1.—A man aged 27, in robust health, was given half a drachm of the bromide of ammonium in an ounce of water, with a little syrup, every four hours. The first dose was given at eight, the next at twelve, the third at four, and the fourth at eight P.M. Nothing unusual was observed at night beyond an alteration in the sense of taste. Next day the dose was continued, and the taste gradually diminished until, at night, there was complete loss of it, and insensibility of the throat and fauces. The application of metallic or other substances was not felt, and apparently anything could have been done with the individual. The sense of smell was affected; the nose, however, did possess some sensation, and also the conjunctivæ. The mucous membrane was pale, watery, and not congested. Although taste was gone, he felt he had a tongue, and could swallow as usual, for the muscles retained their contractile power. Nothing else was specially observed, and in three days all the natural functions were restored, and sensation was quite regained.

Exp. 2.—The same experiment was repeated with the bromide of potassium in another man aged 32; and beyond some amount of nausea, slight headache, and very slight impairment of sensation and taste, nothing further was observed.

Exp. 3.—A man aged 37, in good health, with the exception of chronic hoarseness, was ordered half a drachm of the bromide of ammonium three times a day; this was regularly taken for three days, in all nine doses, equal to four and a half drachms. On the fourth day, although sensation was blunted, it was not absent, for the man had had a bilious attack just before commencing the salt, followed by vomiting. I now gave him thirty grains on the spot, and ordered two other similar quantities during the afternoon. These latter he did not take; nevertheless I succeeded in passing a little instrument into his windpipe with comparatively little or no sensation until it touched the epiglottis, when it was at once rejected. I now ordered him four doses of half a drachm each for the next day, beginning at three P.M., so that on the morning after he would have just swallowed the fourth before coming to me. This he did most punctually; and when he was examined, there was complete anæsthesia of the mucous membrane of the fauces, nose, eyes, and eyelids. He had little or no taste, and no sensation in swallowing food, impaired smell, looked a little pale, but otherwise said he was well. Several times were instruments passed into the larynx without sensation, until they touched the epiglottis, and reflex action compelled their withdrawal. He was now given chloroform to insensibility; and on recovering from it, the anæsthesia of the mucous membrane still remained, so that the

* Journ. de Pharm., Dec. 1849.

whole of the eye could be touched with perfect impunity without winking. Two days after this most of these effects had disappeared, a previously haggard look had gone, and he felt all right again. Four days later he was perfectly well. He had taken altogether seven drachms of the salt.

Exp. 4.—Male, aged 42, health good. For three weeks the salt was given in doses of from four to eight grains thrice a day, which diminished the sensibility of the fauces. In the next two days half-drachm doses were given thrice a day; and as insensibility was not complete, a scruple was given every three hours for two days more. The result of this was complete anæsthesia, so that bodies could be introduced into the larynx; but, as in the previous experiment, when coming into contact with the epiglottis, they had to be withdrawn from the excitation of reflex action. In from five to seven days sensation was quite regained, and all the functions restored without any inconvenience.

Exp. 5.—Male, aged 51, health good, excepting a laryngeal voice. For fifteen days he was given at first $2\frac{1}{2}$ and then 5 grains of the salt twice a day, with no noticeable effect beyond improving the appetite, voice, and complexion. He was then given twenty grains of the bromide four times a day for four days; and on the morning of the fifth day there was anæsthesia of the fauces, nose, mouth, and tongue; and all the special senses were somewhat affected. The stomach likewise, for he had no desire for food, although feeling well in health; and he had little or no sensation in micturition. The countenance was paler than usual, the skin very clear, and the tongue clean. Differing from previous cases, the epiglottis was almost completely insensible, and but feebly influenced by the contact of instruments passed into the trachea. Next day he felt a little giddy and stupid; but in the three following days the senses of taste and smell were returning, appetite indifferent, tongue much furred, intestinal and renal secretions regular and normal in quantity, and sensation restored to the urethra.

Eight days later he was sleepless, and had no desire for food nor for sleep; a bitter taste was present in the mouth, with an odour of ptyalism; the primæ viæ were disordered: throat was now sensitive. In a few days all these symptoms disappeared; but it must be stated that they were partly due to an attack of cold from which he was then suffering.

Exp. 6.—As in the first experiment, half a drachm of the salt was given to a man aged 35, in good health, every two hours, using chiefly a tea and bread diet. During the first day he took four drachms, the second the same quantity, and the third a similar quantity, when it had to be stopped. The symptoms the first day were very much like those in Exp. 1; on the second there was some giddiness and stupor, with impairment of sensation both in the skin and mucous membrane, but not amounting to complete anæsthesia; on the third day he had passed a restless night, and towards evening he was like a man intoxicated; he felt light-headed and drowsy; speech, hearing, and sight were materially affected; he had no sense of smell nor taste, nor any sensation in the mucous membrane of the throat, nose, ears, eyelids, and alimentary canal. Pressure was scarcely felt over the stomach and bowels; there was no sensation in the urethra, and but little in the rectum; and the bladder would have been distended if he had not been requested to empty it; its contractile power was unimpaired. The sensibility of the skin was blunted, but not gone.

General anæsthesia of the entire mucous tract, more or less, had been here produced, and it was deemed prudent not to carry out the administration of the salt further; the pulse was slow and regular, and forty-four per

minute; the breathing quiet and tranquil; the membrane of the fauces was secreting a transparent fluid, and there was no congestion. The symptoms were allowed to subside *sua sponte*. The salt was readily detected in the urine the first and subsequent days, and also in the saliva. In four days sensation had returned in the upper mucous tract, and then in the lower. Some nausea and anorexia remained for a week or ten days, and he regained his normal condition. All his powers were wholly unimpaired.

Exp. 7.—Precisely similar steps were followed out with the bromide of potassium in a man aged 42 in good health, but the general results were by no means similar as affecting sensation. It was impaired, and slight anæsthesia was produced in the fauces. Yet the stupor was not so great, but headache was a prominent symptom, subsequently followed by giddiness and derangement of the digestive organs.

Estimating the power of the two agents, the ammonium salt appeared to be more active, and produced the peculiar effects of bromine quicker than the potassium salt.

In Experiments 6 and 7, four drachms of the respective salts were taken each day for three days, equivalent to $1\frac{1}{2}$ ounce. In the following the quantity was increased.

Exp. 8.—A young man, aged 23, ruddy complexion, health good, voice weak, was given half a drachm every hour for twelve hours, beginning at seven in the morning. It was regularly taken with a drachm of the tincture of cardamoms to each dose. By the seventh dose, nausea and headache were produced; these were lessened by the ninth, and at the tenth stupidity and drowsiness were manifest. When the twelfth was taken, intoxication seemed to be present, with incoherency of speech. It was difficult to say whether there was complete anæsthesia from the man's condition, but he seemed to feel nothing, and the conjunctivæ could be touched with the end of the finger without winking. Pricking of the skin was not felt each time it was done. Breathing was slow, and the pulse fifty-two, quite regular. He slept very sound that night, and the next few days he felt giddy and confused, with impaired sensation of the mucous membrane of the fauces for two or three days, but recovered well. The quantity taken in twelve hours was six drachms.

Exp. 9.—The same experiment was repeated in a female of 32, in fair average health. Nothing particular was observed whilst taking the drug beyond a little pallor, and reduction of the pulse from eighty to sixty-four. At night she felt more drowsy than usual, and faucial sensibility was diminished. After a sound sleep of some hours during the night, she awoke with a furred tongue and offensive breath, and some nausea. On the third day the catamenia set in very profusely, and continued for some days. In the foregoing experiment, and also in Exp. 8, the bromide was readily detected in the urine.

Exp. 10.—Male, aged 78, in good general health, but seldom sleeping at night, was given ten grains twice a day for four days, then fifteen grains for six days, and then twenty grains for twelve days. The digestive functions continued good throughout, and the pulse remained constantly at seventy-six, regular, and with the hardness of old age. His strength was considerably increased, but no other change occurred deserving of note. He was a thin spare man.

Exp. 11.—Twenty grains were given to a female aged 27 twice a day for fourteen days, without any inconvenience beyond losing flesh, and impaired sensibility of the throat.

Exp. 12.—The same quantity was given three times a day to a man of 35, and persisted in for five weeks. At the end of that time he had anorexia and chronic anæsthesia of the throat, *i. e.* impaired sensibility, which had been present for ten days. It was also diminished in the conjunctivæ and nostrils; rhinoscopy was very easy.

Exp. 13.—Thirty grains were given to a woman twice a day for a fortnight, and the symptoms produced were not unlike those in the previous experiment.

Exp. 14.—A similar quantity, three times a day, was given to a young man of 26. He took it well for six days, when it had to be stopped, for he felt light-headed and queer, with some restlessness of the limbs. The mucous membrane of the fauces was feebly sensible, and could be freely touched without any inconvenience or resistance.

Exp. 15.—In another person, thirty grains given three times a day for ten days produced no decided change whatever beyond altering the complexion.

Exp. 16.—Half a drachm was injected into the rectum of a male aged 31 every four hours for two days. It was readily detected in the urine, and exerted its influence chiefly in diminishing sensation in the genito-urinary tract of mucous membrane and lower part of the alimentary canal, which felt benumbed. It seemed also as if sensation was diminished in the fauces.

Exp. 17.—The same experiment, repeated upon another man, caused a slight attack of diarrhœa, but sensation was nevertheless sensibly impaired.

Exp. 18.—A scruple in half an ounce of water was injected into the male bladder, and repeated twice at intervals of two hours. It was quickly absorbed, for reagents indicated the presence of but a small quantity in the urine voided before each recurrence of the injection. Very slight anæsthesia was experienced at the neck of the bladder; and in seven hours from the first injection there was copious diuresis.

Exp. 19.—An eight-ounce mixture, containing half a drachm of each of the iodide and bromide of ammonium, was ordered in tablespoonful-doses twice a day to a healthy female aged 22. The first dose caused severe sickness and vomiting, with great prostration and syncope; severe abdominal pain, but no diarrhœa. She remained very poorly the remainder of the day.

Exp. 20.—A similar mixture, containing a drachm each of the two salts, was ordered for a female aged 28, with aphonia—on the same day as in the preceding experiment. The first dose was swallowed at the chemist's, and on her way home she was seized with sickness and vomiting, great pain in the bowels, prostration and diarrhœa. Next day she was well again.

Although the symptoms were the same in each experiment, excepting the presence in one and absence in the other of diarrhœa, yet they clearly proved that the salts of iodine and bromine are incompatible. I did not like to repeat the experiment. In Exp. 19 the quantity of each salt taken was about two grains, whilst in Exp. 20 it was about four grains. The general symptoms were certainly severer in the latter, which may account for the presence of the diarrhœa.

I have performed several experiments upon animals with bromide of ammonium, and have given various quantities by the stomach, with comparatively no inconvenience, and they rather go to prove that tolerably large doses may be given even to very young children without any ill effect; indeed I have administered pretty large doses to infants and children for hooping-cough and other diseases, with the most satisfactory results.

I have not injected solutions of the salt into the circulation in animals, for the reason that no valuable or practicable inferences would have been fur-

nished, beyond the mere fact that death would have ensued from almost any quantity, as in Dr. Glover's experiments with the sister salt, the bromide of potassium. Nor have I destroyed one single life, nor caused a pang of misery to any dumb creature,—not that I disapprove of such experiments if imperatively demanded by the exigencies of science.

In some of the foregoing experiments it will be observed that whilst large doses, frequently repeated, produced certain specific results in the majority of persons, in some these were comparatively slight, depending most probably upon some idiosyncrasial influence, antagonistic to the bromine salt.

The skin is seldom devoid of sensation, unless large and poisonous doses are persisted in; the same may be said of the gastro-intestinal tract of mucous membrane, which I infer to be equally in a state of anæsthesia from insensibility to pressure over the abdomen, and the presence of anorexia. Two sets of nerves are evidently influenced, those of special sensation, and some of the branches of the sympathetic supplying the intestinal mucous tract; why this should be so I shall not undertake to explain, but the fact is patent that the entire mucous tract of the body is more or less affected in sensation by large and continuous doses. The respiratory tract I also infer to be included in this, from the subsidence of any irritation giving rise to cough or spasm; no impediment to breathing has ever been noticed.

It may not be out of place to mention here that the sister salt, bromide of potassium, is given at the hospital for epilepsy and paralysis in London, in from ten to twenty, and sometimes thirty grains, three times a day, as I learn from Dr. Jackson, one of the physicians. He further informs me that the patients there have not been observed to get notably thinner, nor has he noticed any special symptoms after the use of the salt, beyond the alleviation of their maladies.

Effects on Atheroma, Cholesterine, and Fat in the general economy.—Whether given in small, frequently repeated (two to five grains thrice a day), or in moderately large, less frequent doses (five to ten or fifteen grains once to three times a day), a distinct influence was noticed upon the various agents which more or less constitute the adipose element throughout the body—a result that at first was quite unexpected upon my part.

Various degrees of rotundity, increasing to positive corpulence or polysarcia, in persons otherwise in good health, yet in whom there was a decided and positive indication of excess of atheroma and cholesterine in the system as manifested by the presence of the atheromatous expression*, were sensibly affected according to the period of administration, the dose, or the combination of the drug with a certain moderate dietetic regimen.

Of some five-and-thirty cases, in which corpulence may be said to have been present in various degrees, in all, with some five or six exceptions, did the bromide of ammonium exert a decided effect in diminishing weight and improving the general comfort. That is to say, when this agent was persisted in for some months, and in doses of three or four grains twice or three times a day, several pounds in weight were gradually lost, and the individuals seemed to get thinner; nevertheless the general health continued unimpaired, or improved still further under its use, the adipose development became decidedly less, the secretion from the oily sudoriparous glands, seen in a shining face, was modified and diminished, and altogether there was an improved appearance in the countenance, which the persons themselves were fully sensible of. But when the diet was moderately regulated, and the drug given in the mornings only before breakfast, the reduction in weight was more speedy, more decided and

* For a description of this, see a paper by the author in 'The Lancet' of May 12, 1860.

permanent, and the general health continued excellent. In most of my earlier experiments the pure bromide of ammonium was used to bring about these various results. I am now in the habit, however, of directing from one to three (or more) teaspoonfuls of the effervescing bromide, an elegant and most agreeable salt prepared by Messrs. Fincham, of Baker Street, London, to be taken before breakfast, in water, to neutralize or combine with the various fatty agents in the economy, which so materially aid in shortening the period of human existence. It may be here mentioned that a drachm of the effervescing bromide contains two grains of the salt, and that this quantity is equivalent to a teaspoonful. If it is desired to give this agent but once daily, no better form could be chosen, as four or six grains of the pure salt may be thus administered with great comfort and certainty. It does not undergo decomposition in the stomach, but is absorbed or acts in its condition of bromide.

Before giving a few illustrative cases, it may be further mentioned that the general use of this agent in many hundreds of different individuals demonstrated some remarkable and striking facts, which an experience of some years, pathologically, will determine the value of, and they are as follows:—When the atheromatous or calcareo-atheromatous expressions have been present, not necessarily associated with corpulence, but where the proneness to adipose changes or development was apparent; and in examples of persons undergoing atheromatous conversions, besides the changes last mentioned, there was noticed a marked clearness in the fatty eye, the arcus or annulus adiposus vel senilis, if present, became less yellow and oily-looking, the face was brighter, the integument not being so greasy, the mental faculties seemed to become more active and the mind sharper, and the bodily energy was certainly greater.

The foregoing changes were significant of others not less important going on within; for although the general health was good, it was quite evident in some that the expression already referred to was an index of atheromatous deposits, and a preponderance of cholesterine in the great blood-vessels springing from the heart, and also in the smaller vessels at the base of the brain. In some there could be no doubt of the coexistence of a large and flabby heart, with true fatty degeneration of its muscular structure, indicated by physical signs which it is not necessary to enter into here.

If the effects of this salt were so manifest in its external aspects, it is but reasonable to assume that the internal were not the less positive and certain. And this seemed to me powerfully confirmed by the increased vigour of the intellect, the increased power in the rhythm of the heart, the soundness in breathing, and the softness of the pulse, with an apparent decrease of the rigidity and hardness of the coats of the blood-vessels at the wrist and some other places.

Exp. 21.—J. F., aged 43, health good, moderately polysarcious, atheromatous expression well marked, annulus adiposus, appetite indifferent, weight 173 lbs. Took three grains bromide of ammonium for seven months. For the first thirteen weeks lost a pound a week, and afterwards from half to three-quarter pound per week, until his weight was reduced to 157 lbs., when it appeared to be stationary. His health continued excellent, and his appetite was better, although he ate a smaller quantity of food.

Exp. 22.—A. D. K., aged 57, a stout corpulent person, weighing 227 lbs., a good example of polysarcia. Health moderate; face red and greasy; eyes congested and fatty, with no arcus; cracked voice from deposit of atheroma in the vocal chords; sweet taste in the mouth constant; no glucosuria; faucial mucous membrane congested, red and oily-looking; appetite at times inordi-

nate. Five grains bromide administered twice a day, and his diet regulated. No change for the first fortnight; in third week 3 lbs. were lost, and then the diminution went on pretty regularly for about four months, averaging about a pound a week; at this time he weighed 208 lbs. The bromide was given in ten-grain doses every morning before breakfast for six weeks, and the decrease in that period was 11 pounds; it now caused a little nausea, and was intermitted for a short time, and yet diminution still went on, and the health became very good. It was resumed in four-grain doses in the morning, and after the lapse of ten months from the commencement he had lost 53 pounds, which brought him, he said, to something like his normal standard. He has latterly been taking the effervescing bromide, which he finds exceedingly grateful to the stomach, but with no very sensible diminution in his weight now. All the other symptoms improved, as in Exp. 21. This person had previously given a long trial to the *Fucus vesiculosus*, until "his vitals turned against it," and without the slightest benefit.

Exp. 23.—Major J., aged 44, very corpulent, with reddish face and stout limbs. Palpitation of the heart and feeling of fulness in the chest, very fond of puddings and port wine, which he said he digested well. Weight 198 lbs., which was uncomfortable, as he was a short man. Eight grains of bromide given twice a day: the puddings were stopped and the port wine changed. In five months there was a loss of 23 lbs., and in another three months $8\frac{1}{2}$ lbs. more, so that he was reduced to $166\frac{1}{2}$ lbs.

Exp. 24.—Mrs. St——, aged 47, moderately stout, but with all the expression of great deposit of atheroma and cholesterine in the vessels. Weight 182 lbs. The bromide was given in the mornings before breakfast only, in doses of six grains. One of the first effects noticed was the subsidence of a most irritable temper, and improvement in the facial expression; this was followed by slow and gradual loss of weight, until in five months she was reduced to 163 lbs. The diet was regulated here as well.

Exp. 25.—Rev. P. J., aged 64, getting so stout that it was a constant source of discomfort; weight 213 lbs. The bromide was given pretty regularly, at first in small doses, then in larger, without any appreciable benefit. An effort was at the same time made to regulate the diet, but great difficulty was experienced in effecting this. The diminution therefore was comparatively slight, more especially as milk was freely indulged in.

Exp. 26.—Mary P——, aged 36, inclined to be stout, with a large flabby heart, and from the facial expression and general appearance, the subject most probably of disease of the large blood-vessels at the heart and base of the brain, taken together with a family history which seemed strongly to confirm it. Weight 162 lbs. The bromide here was most invaluable, for a marked improvement followed, and the weight was reduced sensibly and comfortably, although not more than 11 lbs.

Exp. 27.—Julia D., aged 28, with the atheromatous expression, slight dyspnœa, fair *embonpoint*, good digestion and excellent health. Three-grain doses of the bromide twice a day, taken for many weeks, most sensibly acted on the first three, and she became a little thinner, which was shown by the general loosening of her garments.

Expts. 28, 29, 30.—Three males, aged 27, 32, and 41, who were moderately stout, and in whom from 7 to 14 lbs. were reduced in weight by five grains of the bromide twice a day for seven months.

Expts. 31 and 32.—Two females, aged 39 and 43, also moderately stout, whose weight was likewise diminished in the same ratio, by a similar quantity of the salt taken for six months.

Exp. 33.—Man, aged 37, inclined to become very stout, and an imbiber of much malt liquor, reduced himself in weight 15 lbs. in eight months, by small doses of the salt, almost constantly taken.

Of the remaining dozen cases the diminution in weight was mostly a few pounds, but they were not good examples of polysarcia as in some of the first experiments related. Moderate corpulence or inclination to stoutness were the prevailing features, and the quantity of adipose or other matter therefore to be got rid of was necessarily not large. In some the weight was increased instead of being diminished, which I attributed to increased appetite and the consumption of more food.

The foregoing experiments prove that some peculiar property is possessed by the ammonium salt, through the agency of the blood, in resolving some of the constituents of the adipose element. Whether this is of a chemical nature or otherwise I am not prepared to say, but am disposed to favour the former, for the potassium salt does not appear to possess this property, else it would have attracted attention ere this. And although the ammonium salt alone will in some persons absorb fat as an abnormal element, it is ably assisted by regulating the diet, and prohibiting such articles of food as keep up the tendency to its deposition. Dr. Glover has asserted that the bromides of potassium and sodium have little action of a corrosive character, but I will say of the bromide of ammonium that it has none at all, and assimilates better than either, seldom or never disagreeing even with the food when taken immediately before or after meals. Its influence upon the disease of the inner coats of the blood-vessels I attribute more to its direct chemical agency than to its absorbent powers. Nevertheless, whatever may be the rationale of its operation, it is an agent calculated to prolong life to a good old age, from the remarkable properties it possesses in this respect.

It does not cause atrophy of healthy organs, and curiously enough when given to thin people in small doses, its tonic properties increase the appetite, and thus adds to the weight of the body, which some might consider a physiological paradox, but the circumstance readily explains itself.

The use of the Bromide of Ammonium in Medicine.—The length of the present Report will permit of a brief notice only of the value of the salt in the treatment of disease.

As is the case with the salts of iodine in absorbing hypertrophied structure, so is it with those of bromine, and the bromide of ammonium is not inferior to any other preparation in its powers in this respect. The iodide and bromide of ammonium possess this property, and possibly the chloride of ammonium hereafter may be found also to possess it; for it is well known that between chlorine, bromine, and iodine and their compounds, exact and, as it has been said, beautiful chemical relations subsist. With regard to chlorine, the fact is deserving of remembrance, that persons employed in bleaching-factories lose their fat or other hypertrophied tissues, and become thin without impairment of their general health.

As an absorbent and resolvent, the bromide of ammonium has been used in hypertrophy of the tongue, liver, spleen, heart, thyroid and other glands, and other parts of the body with fair results, and it is strongly recommended for trial, more especially in hypertrophy of the spleen, heart, and early bronchocele.

In various cerebral or nervous affections, such as epilepsy, some forms of mild paralysis, neuralgia, especially of the uterine organs, nervousness, and tremors, and mild forms of cervical neuralgia, it will be found to possess

various degrees of usefulness. It here seems to act as an antispasmodic, for it calms irritation and allays nervous excitability.

Fatty disease of the heart and diseases of the blood-vessels are amenable to it.

Bronchitis, asthma, pertussis, affections of the trachea, throat, antrum, and nose, in fact wherever the mucous membrane is implicated will the salt be found to possess some degree of usefulness.

Some forms of chronic rheumatism and diseases of the skin are benefited by it. And amongst other properties it occasionally possesses that of an emmenagogue, and has proved useful in amenorrhœa.

Administered in certain ways, it may be found hereafter valuable in diseases of the genito-urinary mucous membrane.

In these few remarks I prefer to point out the direction in which the agent may be made useful, than to say much at present upon the subject.

To obtain its good effects it should be given with comparatively few combinations, for the union of its constituents, although by no means readily broken, is at any rate influenced by certain substances which negative its properties. Incompatible substances must especially be avoided, and the antagonism between it and salts of iodine must not be forgotten.

Not the least of its advantages is, that it can be given in those constitutions wherein the preparations of iodine disagree.

General conclusions.—These may be stated as follows:—

1. In small doses, more or less long continued, bromide of ammonium acts as a tonic and absorbent, and exerts its peculiar properties upon the skin and mucous membrane.

2. It diminishes the weight of the body in polysarcia, causing the absorption of fat, cholesterine, and atheroma, when combined with a regulated diet; and this is effected with greater certainty than by any other known substance.

3. It improves the intellectual powers, increases the bodily capacity, and promotes healthy function.

4. Locally it possesses a soothing influence on the mucous membrane, and according to the strength and mode of its application, so does it diminish sensibility.

5. In large, frequently repeated doses, or given at intervals, it influences the entire mucous tract; it affects all the special senses, and produces anæsthesia or impaired sensibility of the various mucous outlets.

6. All the poisonous effects are produced by very large doses as from the bromide of potassium, but in smaller doses it is more certain and reliable, causes no diarrhœa or diuresis, nor anaphrodisiasis, and its special properties are exerted sooner and with less inconvenience.

On the Transmutation of Spectral Rays.—Part I.

By Dr. C. K. Akin.

The discovery of fluorescence, by Professor Stokes, has opened to science a new and wide field of research of the greatest promise; nevertheless, though a few persons have more or less clearly perceived the existence of outlying ground*, no one has actually attempted to carry cultivation beyond the extent from which Prof. Stokes, by his labours, has derived such remarkable

* See Appendix, p. 97.

results; nor has it been but tried to subject the whole field to a systematic survey, by which future investigators might be guided in their researches.

1. The discovery of Prof. Stokes is well known to have consisted in this:—He found that very many substances, upon the incidence of invisible rays of greater refrangibility than the violet, scattered visible rays, and were thence rendered perceptible to the eye, in what would otherwise have been complete darkness; and also, that most of such substances, upon the incidence of ordinary visible rays, had the power to produce, in the diffused (or re-emitted) beam, other visible rays, of less refrangibility than the incident. Such substances Prof. Stokes called *fluorescent.* Now the above facts naturally suggest several questions, to explain which briefly and clearly it is necessary to advert to the constitution of the solar or other similar spectra as evolved by a neutral or non-absorbent prism. Every such spectrum consists of three compartments, distinguished by physiological—or generally, extrinsic—rather than intrinsic peculiarities, but which it is yet necessary for present purposes to consider separately. In order to avoid the mischievous ambiguity attendant on the adoption of the terms actually in use, it is proposed to employ in the sequel the following new nomenclature as applied to the three compartments of the spectrum, and the species of rays which each of them contains. The medium compartment, and the visible rays of which it consists, will be called *Newtonic*; the compartment bordering on the red end of the Newtonic, and the invisible rays composing it, will be called *Herschellic*; finally, the compartment bordering on the violet end of the Newtonic, and the similarly invisible rays of which it is composed, will be called *Ritteric*—the name given being formed in each case from that of the first discoverer of the given species of rays.

2. Considering the different nature of rays as just described, and the convertibility of some of them into others of a different refrangibility exhibited in the phenomena of fluorescence, the question, implying several distinct propositions, must naturally arise in the mind whether, upon the whole, changes in regard to wave-length and refrangibility, or *transmutations* of rays corresponding in number and kind to the following list, may not either spontaneously occur in nature, or be capable of production by experiments specially directed to the purpose, viz.:—

Transmutations

1.	of Ritteric	rays into	less refrangible	Ritteric rays,
2.	„	„	(„)	Newtonic rays,
3.	„	„	(„)	Herschellic rays,
4.	of Newtonic	„	„	Newtonic rays,
5.	„	„	(„)	Herschellic rays,
6.	of Herschellic	„	„	Herschellic rays;
also 7.	„	„	more refrangible	Herschellic rays,
8.	„	„	(„)	Newtonic rays,
9.	„	„	(„)	Ritteric rays,
10.	of Newtonic	„	„	Newtonic rays,
11.	„	„	(„)	Ritteric rays, and
12.	of Ritteric	„	„	Ritteric rays.

3. Of the enumerated list, the transmutations (2) and (4) belong to fluorescence; the question of feasibility extends, hence, only to the remaining ten. Of these, the transmutation (8) deserves most attention, as being, at once, the counterpart of (2), and implying, equally with the latter, a conversion of invisible rays into visible. But, since both the species of transmutations ac-

tually effected belong to the first series only, extending from (1) to (6), any one of the transmutations from (7) to (12), which, instead of as the former a diminution, imply an increase of refrangibility in the transmuted beam, would possess an interest of its own if accomplished. More particularly would this be so in the case of the transmutation (10), which is the counterpart or converse of the transmutation (4) occurring in fluorescence, and which, from its concerning exclusively visible rays, would be, at once, easiest to prove, and, next to (8), practically most important.

It is the object of this paper to propose three several experiments, which, it is supposed, would be found capable of realizing the two transmutations (8) and (10) spoken of above. The mode of conducting each of them, as applicable to the transmutation (8), is described in what follows.

Experiment I.

4. The oxyhydrogen flame is well known to excite in lime, chalk, and other similar substances a most brilliant light, if brought into contact with them. The flame by itself, on the contrary, is but sparingly visible, and hence deficient in Newtonic rays; whilst, from the experiment mentioned below*, it appears similarly poor in Ritteric rays. Considering these circumstances, and the high calefactory power of the oxyhydrogen flame, it seems fair to conclude that the rays principally emitted by it are of the Herschellic species. Now the Newtonic rays emanating from the flame upon the introduction of lime, &c.,—which, there is reason to believe, are accompanied also by a strong beam of Ritteric rays,—cannot but be owing to a transmutation, *in statu nascenti* so to speak, of the rays originally emitted by the flame when free from foreign matter, and therefore most probably evidence a phenomenon of the kind which it is intended to produce. But, to render the experiment completely similar to those of fluorescence, the following arrangement would have to be adopted.

Let two conjugate mirrors of large size be placed opposite to each other, one containing in its focus the oxyhydrogen flame, the other a piece of chalk or lime. Let, further, absorbents be employed to cut off as many of the Newtonic and Ritteric rays as the flame may be found to emit, from access to the focus wherein the lime is placed. If the mirrors are of sufficient size to render the temperature at the distant focus approximately equal to that of the flame itself, there is every reason to believe that the lime therein contained will begin to shine out, or, in other words, will emit Newtonic rays consequent upon the incidence of Herschellic rays, in the same way as a fluorescent substance emits Newtonic rays consequent upon the incidence of Ritteric rays. The possible duration of the luminosity thus produced beyond the time of

* Prof. W. A. Miller has observed (see Chem. News, March 21, 1863) that the photographic impression produced by an oxyhydrogen flame, after twenty seconds' exposure of the sensitive paper, was very faint; the impression produced by lime-light, after the same time, being, on the contrary, very strong. Seeing that the chemical action of Newtonic rays is generally less than that of Ritteric rays, this observation tends to demonstrate the deficiency of the oxyhydrogen flame in Ritteric rays when in its natural state, and at the same time to indicate that the transmutations taking place in the flame upon the introduction of lime are of the nature supposed in the text.

[On the reading of the present Paper at Newcastle, Prof. Miller, being present, mentioned the following further fact, of similar tendency:—The rays of the oxyhydrogen flame, if concentrated by a glass lens upon an ordinary thermoscope, produce little or no effect before the introduction of lime, but a considerable effect after its introduction. This seems to be owing to the diminished absorption which glass exercises upon the more refrangible rays as compared with the less refrangible.]

incidence of the rays of the flame would in no way subvert the similarity just pointed out*.

Experiment II.

5. The foregoing experiment recommends itself for the reason of the almost total absence of Newtonic and Ritteric rays from the ray-producing source, whose presence, at least for the production of the transmutation (8), is not wanted. On the other hand, the execution of the experiment would be liable to considerable practical, if not other, difficulties; and hence that next to be described may be considered as, upon the whole, perhaps, more hopeful.

Let, as radiating source, the sun be chosen, and, as test-object, a piece of metal—best of all a thin piece of platinum-foil, which place in the focus of a large mirror exposed to the sun. If the mirror be of sufficient size, the platinum will become incandescent, and may even melt†. Let the former result only be supposed to happen. All the three kinds of rays, Ritteric, Newtonic, and Herschellic, being present at the focus of the mirror, each will have contributed a certain share to the production of the temperature of incandescence of the piece of platinum exposed to their joint calorific action. Let this action, so far as the Ritteric and Newtonic rays jointly are concerned, be represented by α, and that of the Herschellic rays, by themselves, be denoted by β. If the two former species of rays be prevented by absorbents from reaching the platinum‡, but the deficiency of calorific action caused by their withdrawal be replaced, either by employing a mirror capable of concentrating a pencil of Herschellic rays of the separate calorific action $(\alpha+\beta)$, or by some other independent means, then there does not appear any reason why the platinum should not be rendered incandescent, or made to emit Newtonic rays upon the sole incidence of Herschellic rays, as heretofore upon the incidence of the unsifted solar beams. An experiment of this nature would bear the closest similarity to those by which fluorescent phenomena were first of all discovered.

Experiment III.

6. The third and last experiment to be proposed is founded upon the following considerations:—

Fluorescence Prof. Stokes is inclined to consider as owing to the vibrations of the material molecules of matter when acted upon by incident rays§. Adopting this view of the matter, and recollecting that each substance by itself constitutes a distinct source of rays, the efficiency of which depends on temperature or on impressed molecular motion, it is natural to suppose that, in the rays emitted in the act of fluorescence, the spontaneous and incident become blended in a certain manner by some kind of interference. That this is true to some extent seems to result, among others, from the observed influence of temperature on the power of substances to fluoresce‖; consequently, the law established by Prof. Stokes with reference to all fluorescent phenomena may be shown to be capable of a different construction from that usually put on it. Remembering that the incident rays, in fluorescence, are either

* Cf. Part II. Art. 4, p. 102.

† Cf. *e. g.* the accounts of experiments with burning-mirrors in Phil. Trans. 1686, (vol. xvi.) p. 352, and 1719, (vol. xxx.) p. 976, some of which refer, if not actually to platinum, to silver, which is almost equally refractory.

‡ For simplicity, the absorption which the Herschellic rays would, practically, undergo simultaneously with the remainder has been left out of consideration.

§ Phil. Trans. 1852, p. 548.

‖ See (Prof. Stokes) Phil. Trans. 1852, p. 532 and; (M. O. Fiebig) Pogg. Ann. vol. cxiv. p. 292 (1861).

Ritteric or Newtonic; whilst the spontaneous rays of substances, at the temperatures at which their fluorescent nature has been investigated, are of the Herschellic species; the transmuted or resultant rays, finally, being of the Newtonic species; the law adverted to, which requires the transmuted rays to be of inferior refrangibility to the incident, may be interpreted also as implying that the transmuted ray should be *of a mean* between the incident and spontaneous in regard to refrangibility*. Assuming such to be the case, the question becomes natural whether, if the order of the rays employed in ordinary fluorescence were reversed, by taking for test-object a substance naturally emitting Ritteric rays (either alone or in sensible proportion with others), and allowing Herschellic rays to be incident on it, the result might not be the same as in fluorescence—namely, an emission of Newtonic rays, seeing that the circumstances of the experiment, though reversed, are essentially the same in the two cases.

7. As objects of experiment, many different kinds of flame might be employed, as, likewise, the electric vacuum-discharge. Upon the whole, however, of the three experiments proposed, least reliance should perhaps be placed on the present, as having the least basis of fact, but principally conjecture, to rest upon. The views upon which it is founded imply also a contradiction of the principles by which the preceding two experiments are supported, and, if pushed to extremes, would similarly be in opposition to certain facts of fluorescence; nevertheless they will probably be found to accord with truth within limits.

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8. The question which has been advanced for solution in this paper, and the experiments proposed, might naturally lead to the consideration of some incidental subjects, the most important of which may be worthy of mention. The first experiment suggests an investigation of the mode of action of foreign matter, whether in the solid or gaseous states, upon comburescent gases or flames with reference to the rays emitted by the same; the second experiment involves some discussion of the incandescence of matter in its relations to various other similar phenomena; whilst the third might throw some light on the action of gaseous incandescent matter upon rays in general. The bearing of all the three experiments, and the considerations which they imply, on the subject of ray-absorption are too evident to need pointing out.

Appendix.

9. In this Appendix it is intended to present a short historical review of the several publications on the collateral phenomena of fluorescence, alluded to in the beginning of this paper, which have come to the knowledge of the author. They almost all owe their origin to the following observation by Fusinieri, which, however, is generally, though erroneously, ascribed to Melloni. Fusinieri had noticed, and published his observation as early as the

* The account of the origin of fluorescence given by Prof. Stokes (see Phil. Trans. 1852, p. 584) seems to leave it doubtful whether fluorescence depends on the cooperation of the spontaneous rays with the incident, or not; for, though some kind of interference is mentioned, the expression seems to refer to the successive impulses given to a molecule by a continually impinging ray, rather than to the mutual action of the incident and spontaneous rays. On the other hand, though independently formed, the speculations put forth in the text bear some similarity to the theory of fluorescence suggested by M. Lommel, in Pogg. Ann. vol. cxvii. p. 642 (Dec. 1862). This writer, however, mistakes in stating that the wave-length of the transmuted beam is necessarily equal to the difference of the wave-lengths of the incident and spontaneous rays, which is not in accordance with facts.

year 1831*, that snow shaded by trees, or generally by objects suspended from the ground, melted more rapidly than snow freely exposed to the radiating action of the sun or skies. To explain this apparently anomalous fact, Melloni thought it sufficient, in his comments† on a later paper by Fusinieri on the same subject‡, to ascribe to snow a difference of absorptive powers for different rays, which he attempted also to prove by direct experiment. He denies that a conversion of light into heat—or, as we should more correctly express it, of Newtonic into Herschellic rays—can account for the effects observed, thinking the assumption to be disproved by the following experiment. The incidence of the rays emanating from some lamp produced in a thermoelectric pile § a current which, measured by the galvanometer attached, was equal to 15° when the rays passed freely through the air, but of 30°·5 when the rays were first transmitted through a sheet of paper. When the rays were first of all transmitted through glass rendered opake by lamp-black, the resultant current was as 18°–19° to 10°–11°, according as the paper also was interposed or not. As the increase of calorific effect upon the interposition of the paper sheet thus occurred in the absence as well as in the presence of light—that is to say, of visible or Newtonic rays,—Melloni concludes that a conversion of the latter into heat—or, as we should say, into Herschellic rays—cannot be the cause of the augmentation observed. This argument, however, as well as the explanation attempted by Melloni himself, is evidently fallacious. To the latter, already Fusinieri very reasonably objected || that, since the direct beam issuing from a radiating source must necessarily contain all the rays to be found in the same after diffusion or reflection ¶—besides, generally, others,—the diffused or reflected beam could never offer to any substance more rays absorbable by it than the direct beam. On the other hand, Melloni's experiment, so far from disproving the conversion of visible into other rays, tends rather to prove that, besides this conversion, a transmutation of invisible rays also into others, probably of less refrangibility, is possible; since the interposition of the paper sheet, in the absence of visible rays, still produced an increase of calorific action of 8°, against the 18°·5 which it caused in the presence of light**. As for Fusinieri's own speculations on the subject, it is unnecessary to advert to them, since, besides not being clear, his explanation involves the materiality of rays, and proceeds from a negation of the discoveries of Melloni with reference to radiant heat.

10. In 1861, Prince Salm called attention to Fusinieri's observation, as the author of which he names Melloni††. Without entering further into the matter, M. Salm considers the fact as proving the *fluorescence of heat*,—leaving it doubtful to some extent what the meaning is which he attaches to the expression.

11. Induced by the above, M. Emsmann published in 1861 a note ‡‡, in which he quotes a paragraph from an article contributed by him, in 1859, to

* Annali delle Scienze, vol. i. p. 196.

† Comptes Rendus, vol. vi. p. 801 (1838).

‡ Annali delle Scienze, vol. viii. p. 38 (1838).

§ It may be useful to mention that the exposed face of the thermo-electric pile was covered with white-lead.

|| Annali delle Scienze, vol. viii. p. 227.

¶ Cases of ray-transmutation excepted, the occurrence of which Melloni strives to disprove.

** Another instance in which the interposition of a screen produced an augmentation of calorific effect was mentioned by Melloni, upon an earlier occasion, in Ann. de Chim. et de Phys. vol. lv. p. 387 (1834) Also Taylor's Scientific Memoirs, vol. i. p. 68 (1837).

†† Pogg. Ann. vol. cxiii. p. 54 (1861).

‡‡ Pogg. Ann. vol. cxiv. p. 651 (1861).

Cornelius and Marbach's 'Physikal. Lexicon,' showing that he then entertained the question of the possibility of phenomena the reverse of fluorescence, or of the transmutation of Herschellic into Newtonic rays. In the sequel, however, M. Emsmann adduces facts which in his opinion exemplify phenomena of this kind, rendering thereby his estimation of what constitutes fluorescence, or its converse, of doubtful clearness. Iodide of mercury, which is commonly scarlet, upon sublimation becomes transformed into yellow crystals, which may be preserved for some time; several other substances exhibit similar changes of colour. Steel also alters its colour by heating. In all these instances, according to M. Emsmann, by the action of heating, "that is to say, by heat-vibrations," substances are made to *reflect* rays of higher refrangibility than would otherwise happen. Similarly, the rays emitted by incandescent matter increase in refrangibility with the increase of temperature.

Now it is easy to show that none of these facts in the least exemplify what they are intended for. In the first place, substances which change their colour in consequence of heating do so, generally, by selecting different rays for simple diffusion in their several states; if the incident beam was deficient in the rays which are reflexible, or consisted merely of invisible rays, then such a substance would turn black. This is the case with the iodide of mercury for instance. Such substances, on the other hand, which, being self-luminous, assume different tints at different temperatures, as, for instance, incandescent metals, do so independently of incident rays, or, at any rate, not in a manner proving obviously or necessarily the transmutation of Herschellic into Newtonic rays. Nor does this fact show that, similarly as "the dark chemical (or Ritteric) rays may produce modifications of one kind in the colour of the luminous (or Newtonic)," so also the dark heat (or Herschellic) rays may modify the colour of the same rays in an opposite direction—in which way M. Emsmann defines fluorescence and its converse in one place. As for steel, its coloration is generally supposed to be simply an instance of the coloration of thin plates; so that, upon the whole, none of the phenomena adduced can be considered as bearing any resemblance to those of fluorescence, or those which might be conceived as its counterpart.

12. Another publication is by M. Dammer*, who observed in the winter of 1862 a fact already noticed by Fusinieri, if not in exactly the same way, that ice beneath leaves, whether imbedded on the surface or in the midst of the crust, melts sooner than ice freely exposed to the rays of the sun. This, according to M. Dammer, is a phenomenon analogous to that adverted to by M. Salm. The fact, however, may be dependent rather on conduction than on radiation, and hence capable of explanation without the aid of assumed transmutations. It is, besides, to some extent similar to one of Franklin's observations †, which, though directed to show differences dependent on colour, incidentally proved also that snow beneath strips of cloth melted more rapidly than if uncovered.

13. In conclusion, it will be but just to state that Prof. Stokes, in his paper on fluorescence ‡, had adverted to the probability that transmutations of visible (Newtonic) into invisible (Herschellic) rays might account for the disappearance of light in cases of ray-absorption which cannot be classed under fluorescence.

* Pogg. Ann. vol. cxv. p. 659 (1862).

† 'Letters and Papers on Philosophical Subjects' (Appendix to 'Exp. and Obs. on Electricity'), London, 1769, p. 465.

‡ Phil. Trans. 1852, p. 554.

Part II.

In the first part of this paper three experiments were described, having for purpose the production of the converse phenomenon of fluorescence. It is the object of this second part to discuss in greater detail one of the experiments proposed, viz. the second, in its relations especially to the subjects of phosphorescence and incandescence.

1. The luminosity of matter, or the emission (in the language explained in the preceding part) of Newtonic rays—as well as radiation upon the whole—may arise in a twofold manner, which it seems important to distinguish. In the first case, there is a production of light by certain processes which do not imply pre-existing radiations; whilst, in the other, only a reproduction and communication of rays actually takes place. Above and beyond these, a third case, of what, for the present at least, must be called spontaneous radiation, may be distinguished; to which has to be referred the luminosity of the sun for instance, and of the fixed stars. In these latter instances, no adequate cause can be, or has hitherto been, assigned for the light emitted, except (if we suppose the radiascent state to indicate molecular vibrations) a certain velocity impressed on the molecules from all beginning and certain inter-molecular relations, corresponding in some degree to the tangential tendency and gravitating force which rule the motions of the heavenly bodies*.

2. The causes of production of light, as of rays generally, may be considered as threefold, viz.—1, morphological and chemical; 2, electrical; and 3, mechanical. The cases of reproduction, on the other hand, appear separable into two classes, according as the matter whose radiascence is considered is in immediate contact with the primarily radiating source, or not. The first kind of reproduction—to make our meaning clear—is exemplified principally in the phenomena of ignition exhibited by foreign matter, such as precipitated carbon-particles or certain vapours, mixed with comburescent gases or flames; or by such instances as the incandescence of platinum wire in the common gas-flame, or of lime in the oxyhydrogen flame. The second kind of reproduction, on the other hand, comprises all such appearances of light as are caused by the incidence of radiations emanating from distant sources, as, for instance, the sun, and presents to our consideration two different orders of phenomena, which require to be kept apart. The necessity of this distinction is, first of all, suggested by the fact that the rays reproduced by the secondary radiator are sometimes identical with, but at others different from, those emitted by the primary radiator as to the characteristic of wave-length or refrangibility; but there are cases which, without implying any such change, belong yet to the same class as those which do. As the operative cause of this distinction, the best authorities seem to be agreed in considering the compound nature of matter; the one kind of reproduction, ordinarily termed *diffusion*, being ascribed to the agency of ether, whilst the other kind, which is generally if not always accompanied by transmutation (in the sense of the word explained in the preceding part), and for which the term *renovation* might perhaps be suitably adopted, is assumed to arise from the intervention of the ponderable molecules of matter †.

3. The mode of reproduction which has been noticed in the first place, and which occurs on the *contact* of radiascent substances of different natures, may

* The above simile was employed already by Sir H. Davy, in his 'Essay on Heat, Light, and the Combination of Light' (see Works, vol. ii. p. 15), though not quite consistently applied throughout.

† Cf. (Prof. Stokes) Phil. Trans. 1852, p. 548; also (Dr. Young) Phil. Trans. 1802, p. 47. M. Ångström (see Phil. Mag. xxiv. 2. 1862) seems to entertain a different opinion.

with great probability be considered as coming under the head of renovation. The most remarkable instances of this kind are those in which light is engendered by the contact of two non-luminous substances, generally of different temperatures. The earliest well-substantiated instance of this description seems to be afforded by Boyle's experiments on the celebrated Clayton diamond, which became luminous in a dark room by contact with an iron plate heated to a temperature below redness, or with warm parts of the human body*. A similar though perhaps not quite the same phenomenon was noticed by Canton, whose artificial phosphorus, after exposure to light and subsidence into apparent darkness, had its light restored by the application of heated non-luminous matter†. In the case of Canton's phosphorus, the necessity of a previous exposure to light in order to produce the phenomenon just described seems to be rigorously established, but with regard to diamonds it is perhaps still doubtful‡. It is equally undecided whether some kind of morphological change, or combustion, or nothing of the kind, causes or accompanies this evolution of light upon the contact of dark unequably heated bodies. The observations of Sir D. Brewster on the loss of colour which green fluor-spar exhibits after calcination, simultaneously with the loss of ability to shine by subsequent exposure to light or to high temperatures§, at first sight would indicate that colouring-matter or its combustion are the cause of the luminosity observed before calcination, which ceases of course after the expulsion of the colouring-matter, which takes place at the higher temperatures. But the observations of Dessaignes ‖ on the revival of the phosphorescent power through electrical shocks, which, according to Pearsall ¶, is attended by a restoration of colour, do not seem to countenance such an opinion, but rather to point to molecular disarrangement as the cause both of the phosphorescence and its destruction.

Other though less clear examples of ray-renovation on the contact of two radiators of different descriptions have been alluded to in that part of the preceding paragraph which refers to the phenomena of flame. These appear to show that matter, whether in the solid or gaseous state, introduced into gaseous comburescent substances, may change the rays emitted by the same, as it were *in statu nascenti*; or take upon itself, seemingly, the function of principal radiator. One of these phenomena has suggested the speculations contained in the present paper, and serves as foundation for one of the three experiments proposed in the preceding part; a full consideration of the whole subject, however, is reserved for a future occasion**.

4. The renovation and transmutation of rays incident from *distant* radi-

* Appendix to 'Considerations, &c., touching Colours,' London, 1764, p. 416. The phosphorescence of diamonds, consequent on insolation, was first noticed by Dr. Wall (see Phil. Trans. 1704–5, p. 69).

† Phil. Trans. 1768, p. 342.

‡ Cf. Priestley's 'History, &c., of Light, &c.,' p. 373; and (M. O. Fiebig) Pogg. Ann. vol. cxiv. p. 292 (1861).

§ Edinb. Phil. Journ. vol. i. p. 386 (1819).

‖ Journ. de Phys. vol. lxxi. p. 67 (1810); also *ibid.* vol. lxviii. p. 465 (1809).

¶ Journ. Roy. Inst. vol. i. p. 277 (1831). It should be observed that the colour given to fluor-spar by electricity is not generally the same as possessed by the mineral before calcination.

** A remarkable example of a phenomenon in many respects similar to those of flames, adverted to in the text, is exhibited in the ingenious experiment performed by Mr. Wedgwood (see Phil. Trans. 1792, p. 271), in which, by a hot stream of non-luminous air, a piece of gold-foil was rendered incandescent. In the same paper, Wedgwood advances also the question, remarkable for its time, "Whether a body can be made red-hot by concentrated rays of other colours." It should be recalled, however, that Wedgwood's views on the nature of, and relation between, light and heat are not those now prevailing.

ating bodies, by the agency of certain kinds of matter, has been principally brought into notice through Prof. Stokes's discovery of fluorescence. It is true that already Benjamin Wilson contended, against Beccaria*, that the light of phosphorescent substances is generally independent as to colour, of the colour of the incident light. It is true also that Wilson sagaciously remarked that the emission of the light of phosphorescence must take place during as well as after action on the part of the active incident light, though it may ordinarily be hidden from observation by the greater intensity of the non-renovated, non-transmuted, diffused light†; both which facts, that referring to colour as well as that referring to time, were clearly proved by the later experiments of Grosser on diamonds‡. It is true, finally, that Seebeck had noticed phosphorescence produced by rays near the violet border of the spectrum, of doubtful visibility, and hence pertaining, perhaps, to the Ritteric compartment§; that M. Matteucci and M. E. Becquerel, later, actually observed phosphorescence to occur in regions of the spectrum undoubtedly forming part of the Ritteric compartment‖; as also, lastly, that M. E. Becquerel, in one or two instances, noticed the occurrence of such phosphorescence during the time of incidence of the active Ritteric rays¶. Still, phosphorescence, before the time whence Prof. Stokes's experiments date, was principally considered as a phenomenon interesting in so far as showing an emission of *light, without reference to colour*, consequent upon and *after* exposure of the given substance to incident *light*. It was Prof. Stokes's discovery, arrived at from quite a different and apparently unpromising starting-point, which first drew general attention to the change of refrangibility which *Newtonic as well as Ritteric rays* may undergo *whilst* incident on properly selected matter**. This, in the end, taught us to consider phosphorescence as only a species of the phenomena just described, distinguished for the protraction of the state of emission by renovation beyond the duration of incidence††. But this quality, to which at first had attached the principal interest, now may be considered as of secondary importance.

The most general law relating to fluorescence, including phosphorescence, has been already adverted to in the preceding part, and is generally expressed

* (Beccaria) Phil. Trans. 1771, p. 212. (Wilson) Journ. de Phys. vol. xv. p. 93 (1780). The same fact which Wilson maintains, had been experimentally established in 1728 by Algarotti, acting upon the suggestion of F. Zanotti (see Comment. Bonon. vol. i. p. 203).

† (Wilson) *l. c.* p. 95. The original work of Wilson on phosphorescence, of which two editions seem to have been published, the author has not been able to consult.

‡ Journ. de Phys. vol. xx. p. 277 (1782).

§ Ibid. Comptes Rendus, vol. xiv. p. 903; being the translation, by Arago, of a passage from the Appendix to the original edition of Goethe's 'Farbenlehre.'

‖ (Matteucci) Bibl. Univ. vol. xl. p. 161 (1842). (E. Becquerel) ibid. p. 360; also Taylor's Scientific Memoirs, vol. iii. p. 552 (1843).

¶ Ann. de Chim. et de Phys. vol. ix. p. 320 (1843).

** The fact, likewise, that liquids, like solids, may act as ray-renovators, was first of all established through the discovery of Prof. Stokes.

†† Cf. Engl. Cycl. (Arts and Sciences) vol. iv. p. 124. Now that the identity, in the main, between phosphorescence and fluorescence has been pointed out, some further facts may be adduced in support of the theory of fluorescence advanced in Part I. Art. 6. Of these new facts, the most interesting (which was first observed by Benjamin Wilson, and later again by Seebeck and others) is the negative or extinguishing action of little-refrangible Newtonic rays upon the state of luminosity of phosphorescent bodies. Another observation, by Canton (see Phil. Trans. 1768, p. 341), has shown the influence which temperature, and hence the spontaneous rays of bodies, have on the duration of phosphorescence; which influence, according to M. E. Becquerel (see Ann. de Chim. et de Phys. vol. lv. p. 102, 1859), extends also to the colour of the light emitted. All these facts tend to prove that the rays emitted by renovation are owing to a kind of interference between the incident and spontaneous; but it would not be difficult to test this view by some more direct experiments.

as requiring the rays emitted by renovation to be of less or, at the utmost, of equal refrangibility to that of the incident*. If this law, of which, however, a different interpretation was proposed in Part I. Art. 6, held good with respect to ray-renovation upon the whole, it is evident that, of the transmutations enumerated in Art. 2 of the previous part, only the first six would be feasible, whilst the remainder would be impossible by the nature of things. Several experiments have been adduced in the preceding part, both to show the probability that phenomena the converse of fluorescence may occur, and to provide for their realization in a way analogous to the ordinary form of fluorescent appearances. The remainder of this paper is devoted to the detailed consideration of some of the circumstances relating to that of the proposed experiments which were designated before as the most hopeful.

5. According to Prof. Draper's experiments†, the incandescent state of metals, and the order of Newtonic rays which they emit, are strictly determined by their temperature, and independent of their nature. Other substances, however, such as chalk, marble, and fluor-spar, become luminous at different temperatures from the metals, which is also the case with gases. Now with respect to metals, if, as stated, their incandescent state is conditional upon a certain temperature alone, it is evident that, in whatsoever manner this temperature be imparted, the result will always be the same, viz. an emission of Newtonic rays. One means for the production of high temperatures is to be found in the concentrated rays of the sun, which produce an effect compounded of the aggregate effects of the different species of rays coexistent in each solar beam. The heating effect of any given kind of rays depends—1, on their amplitude; 2, on the absorptive power of the substance on which they are incident for the particular kind of rays. The calorific power of the solar rays as evolved by a non-absorbent prism and absorbed by lampblack, which has been found to absorb (Newtonic and Herschellic rays at least) more equably and completely than any other known substance, has been investigated in a masterly manner by Melloni‡, and more recently again by Prof. Müller, of Fribourg§. Both these philosophers agree in assigning the greatest calorific action to the rays situated in the Herschellic part of the spectrum, at some distance from the red border of the Newtonic; and though the greater crowding which dispersion causes in this part of the spectrum may partially account for this result, it is not liable to any doubt that, independently of that circumstance, the Herschellic bands of the spectrum separately, and still more in the aggregate, possess considerable heating power in comparison with the remainder of the spectrum. Again, the reflective power of the metals for Herschellic rays, though great, is not absolute; and, considering that the supply of Herschellic rays from the sun is almost unlimited, it cannot be doubtful that if the rays of the sun were concentrated by means of a very large mirror, but only their Herschellic components allowed to be incident on a piece of platinum-foil, for instance, placed in the focus, the platinum would be rendered incandescent, in the same way as a cone of unsifted solar beams reflected by a smaller mirror would make it.

At the same time, if, instead of excluding all the Newtonic and Ritteric rays from the focus, some of the less refrangible among the Newtonic were allowed to accompany the Herschellic rays which meet there, there is every reason to believe that, by a suitable adjustment, incandescence might be pro-

* M. E. Becquerel (see Ann. de Chim. et de Phys. vol. lvii. p. 85, 1859) mentions an exception to this law, which, however, as M. Becquerel also considers, is only an apparent one.

† Phil. Mag. vol. xxx. p. 347 (1847). ‡ Bibl. Univ. vol. xlix. p. 141 (1844).

§ Pogg. Ann. vol. cv. p. 350 (1858); also Phil. Mag. vol. xvii. p. 233 (1859).

duced, characterized by rays of greater refrangibility than the most refrangible among the incident Newtonic; so that, by this means, the converse of what may be called the second phenomenon of fluorescence—the transmutation of Newtonic rays into other but less refrangible Newtonic rays—might be effected.

6. Supposing that, by means of the experiment proposed, the transmutation of Herschellic into Newtonic rays, and of Newtonic into more refrangible Newtonic rays, had been successfully performed, there would still remain some difficulties, which, in the opinion of some perhaps, would mar the parallelism between the class of phenomena thus realized and those of ordinary fluorescence. As the most important of these differences the following may be mentioned:—According to Prof. Draper*, incandescent metals emit rays forming an unbroken spectrum, which, with the increase of temperature, extends more and more through the Newtonic in the direction of the Ritteric compartment, whilst retaining all the rays previously emitted. But in fluorescence or phosphorescence, on the contrary, the spectrum of the rays emitted is very often broken in a manner perfectly characteristic of the substance by which they are emitted†. Again, in fluorescence, all the transmuted rays appear of less refrangibility than the active incident; but in incandescence, supposing it was produced by rays of a certain mean refrangibility, most probably both more and less refrangible rays than the incident would be found amongst those of the transmuted beam. The fact also that fluorescence may be excited by rays of comparatively small intensity, whilst the production of incandescence, in any case, requires rays of unusually great intensity, may appear as an objection; but, in regard to this, (besides the doubtful comparability of rays of different quality) it should be considered that the intensity of the active rays required to produce either phenomenon necessarily varies from substance to substance, according to the absorptive powers of each.

Some further discrepancies of a similar nature to the last may yet be instanced. The production of incandescence by irradiation may possibly require time, or, so to speak, a repetition of the irradiation; its duration may be protracted beyond the time of incidence, and its extent not strictly confined to that of the actually irradiated spot. But fluorescence is instantaneous in its appearance and disappearance, as well as definite and limited in regard to extent. As, however, phosphorescence, which outlasts irradiation, seems now to be allowed as a variety of fluorescence, and the other two differences, besides being of doubtful occurrence, also refer to questions of degree rather than of kind, perhaps not too much weight need be attached to them.

7. But, whether incandescence produced by irradiation‡ and fluorescence be parallel phenomena or not, the production of the former, either by means of Herschellic rays only, or by Herschellic and slightly refrangible Newtonic rays (to be exceeded in refrangibility by the transmuted), in a manner analogous to ordinary fluorescent experiments, as described in this paper, cannot but deserve a practical trial. The requirements for such an attempt, in the way of apparatus, consist principally of a large concave mirror, best of all of metal;

* Phil. Mag. vol. xxx. p. 349.

† Cf. (Prof. Stokes) Phil. Trans. 1852, p. 517; (M. E. Becquerel) Ann. de Chim. et de Phys. vol. lvii. tab. 2 (1859).

‡ The term *incandescence* is probably best employed as, in many respects at least, the counterpart of *phosphorescence*, both in its wider and in its more limited meaning. To designate the phenomenon which is the principal subject of the present paper, or the counterpart of fluorescence as defined in Art. 6, the term *calcescence* has been suggested to the author—from *calcium*, the name of the characteristic chemical element of the substance whose action on the oxyhydrogen flame has first of all given rise to the speculations contained in this paper.

a contrivance for viewing the incandescence produced in exterior darkness; and several absorbents, partly for the sifting of the incident beams, and partly for the intercomparison of the transmuted rays with the incident.

Report of the Committee on Fog Signals. By the Rev. Dr. Robinson.

This Committee, consisting of Dr. Robinson, Professor Wheatstone, Dr. Gladstone, and Professor Hennessy, was appointed at Manchester "to confer as to experiments on fog-signals, and to act as a deputation to the Board of Trade in order to impress on that body the importance of inquiries on the subject."

The matter was discussed by them at several meetings of the Committee, both in reference to what is practically known of it, and to methods which, though yet untried, seem to promise better results than any now in use. After mature deliberation, in which they have to acknowledge the valuable aid of Admirals FitzRoy and Washington, it was considered most advisable to embody in a Memorial to the President of the Board of Trade the facts which we had collected, to point out how defective is our knowledge of many things connected with the efficiency of these signals, and to indicate the nature of the experiments which are necessary to complete that knowledge.

In accordance with this decision, I drew up the following Memorial, which, being approved of by the other Members of the Committee, was forwarded to the Right Honourable T. Milner Gibson, M.P., on June 18, 1863.

Memorial.

"Sir,—In consequence of an application from the Belfast Chamber of Commerce and several of the leading merchants of that important city, requesting the British Association to cause experiments to be made with a view to determine what kind of signals are best for indicating to sailors in foggy weather the vicinity and position of a danger, that body, after careful deliberation, came to the conclusion that, from the momentous bearings of such an inquiry on the preservation of property and still more of life, it ought to be regarded as of national importance, and as such was a fit subject for investigation by the Government.

"It therefore appointed a Committee, consisting of

Rev. T. R. Robinson, D.D., F.R.S., *Chairman*,
Charles Wheatstone, F.R.S.,
J. H. Gladstone, Ph.D., F.R.S.,
H. Hennessy, F.R.S.,

and directed them to bring the matter under your consideration,—to point out the defects of the existing fog-signals, and to express a hope that under your auspices some methods may be devised which will, if not entirely remove, yet greatly diminish the chance of such fearful calamities as that which within the last few days has spread sorrow through the land*.

"Nearly all that is known about fog-signals is to be found in the Report on Lights and Beacons; and of it much is little better than conjecture; its substance is as follows:—

"Light is scarcely available for this purpose. Blue lights are used in the Hooghly; but it is not stated at what distance they are visible in fog: their glare may be seen further than their flame. It might, however, be desirable to ascertain how far the electric light or its flash can be traced.

"Sound is the only known means really effective; but about it testimonies

* The loss of the 'Anglo Saxon,' with most of her crew and passengers, in a fog.

are conflicting, and there is scarcely one fact relating to its use as a signal which can be considered as established. Even the most important of all, the distance at which it ceases to be heard, is undecided. But it is the more necessary on this account to lose no time in obtaining results which shall come with such authority that they may command respect and acquiescence.

"Up to the present time all signal-sounds have been made in air, though this medium has grave disadvantages: its own currents interfere with the sound-waves, so that a gun or bell which is heard several miles *down* the wind is inaudible at more than a few furlongs *up* it. A still greater evil is that it is least effective when most needed; for fog is a powerful damper of sound: it is a mixture of air and globules of water, and at each of the innumerable surfaces where these two touch, a portion of the vibration is reflected and lost. This has a familiar illustration in a glass of champagne, which when struck will only give a dull sound while effervescing, but rings clearly when the gas has escaped. Snow produces a similar effect, and one still more injurious.

"Water transmits sound with great power, and seems to possess in some other respects a decided superiority over air, but has been so little studied in this point of view that we can neither pronounce on the best mode of applying its powers or the practical difficulties which we may have to encounter.

"The signal which (judging from the Report referred to) is most approved by sailors is a gun stationed at or near the danger, and fired at intervals, mostly of half an hour; in the case of the Holyhead mail-steamers, of fifteen minutes, when they are expected. The gun must be heavy, and the cost of ammunition is about £200 a year. The Holyhead gun is said to be 'heard in all weathers at Skerries, nine miles off;' but this distance is greater than any other which appears in the evidence. It must be remarked that half-hour intervals are much too long for rapid steamers, which in that time might run seven or eight miles—a space through which the gun could not be heard in thick fog. Against gun-signals there are also the objections that they depend on the punctuality of the signal-men, and that they are often fired by ships in distress.

"Bells and gongs are also extensively used; but we have no exact information as to the proper size, the force of blow required, or the distance at which they can be relied on. In many cases they have been abandoned for guns. The most effective one described is at the Copeland Light, in Belfast Lough, which is tolled by machinery, and is stated to have been heard at thirteen miles' distance. But it must be noted that *this very spot is notorious for wrecks in foggy weather*; so that even this powerful bell is of little avail. The gong of the Warner has been heard at the Nab, three miles off; but several instances are given where bells or gongs could not be heard at a quarter of a mile. The gong is said to be heard best *down* the wind, the bell *up* it. An ingenious contrivance to intensify the sound of a bell, and at the same time to send it in a given direction, has been tried at Boulogne: the bell is put in the focus of a parabolic reflector made of mason-work, which ought to concentrate the sound in the direction of its axis. It seems not to have succeeded well; the sound-rays diffuse more than those of light, and probably the reflexion is imperfect. On the whole, the evidence leaves an impression on the mind that sounds excited by percussion cannot *universally* be trusted for half a mile. Drums seem not to have been tried.

"The third class of signals is made by wind instruments, including in that category those blown by steam. These seem the most promising, but their

efficiency can only be imperfectly estimated in the absence of authentic data. The steam-whistle is the best-known of them, and is stated to act well. It is said that one used in the Bay of Fundy had been heard eight miles *against* the wind (the velocity of which, however, is not given). One witness thinks that in rough weather it is heard further than a gun. It is possible that some loss of sound may take place with it where the steam comes into contact with the air.

"An air-whistle, by Wells, is reported as 'very feeble at $2\frac{3}{10}$ miles;' it was blown by bellows. Horns and trumpets are preferred by some: blown by men, they are said to be heard in Nova Scotia from two to three miles, and probably with steam or condensed air will be much further. The instruments of Holmes* (so well known by his electric light) and of Daboll are said to have great power.

"This summary shows how little is known of the facts on which the efficiency of fog-signals depends, even of that which is the most important—the distance at which they can surely be heard under those circumstances where they are most necessary.

"A. At the outset, it is obvious that, to make experiments *comparable*, we must have some measure of the fog's power of stopping sound, without attending to which the most anomalous results may be expected. It seems probable that this will bear some simple relation to its opacity to light, and that the distance at which a given object, as a flag or pole, disappears may be taken as the measure. It is easily ascertained, and should be noted both at the signal-station and the observing one: the fog may have many fluctuations of density between them; so that this will only be an approximate estimate, but one which will aid in insuring that the signals shall have sufficient power to pass the minimum of efficiency. That minimum is when a ship, putting down her helm on hearing the signal, *can just come round clear of the danger*. For very large steamers this cannot be done in less than two miles; and, allowing for sea and currents, that limit should at least be doubled; so that it may be assumed as a law, that (except in harbour) *all fog-signals should be distinctly audible for at least four miles under every circumstance.*

"B. The range of sound depends on causes not thoroughly understood, and sometimes is very different from what might be expected. Some sounds which near at hand are very loud, as the explosions of fulminating compounds, reach but a very little way. Others fail from want of intensity, though the quantity of sound is enormous: thus thunder, however violent, is not heard at twenty miles' distance, while heavy ordnance is said to have reached two hundred. Experiment can alone decide. It should therefore be ascertained by trial, first, what source of sound (of course among those already mentioned as suitable to this particular object) has the greatest space-penetrating power in still and clear air. Secondly, besides the natural decay of sound due to distance alone, it is, in the case which interests us, stifled by other sounds near the listener. The movements of the crew, the noise of the engines, the rush of the vessel through the sea, the murmur of winds and waves are close at hand to prevent it from being noticed (though still of sufficient power to be heard), unless it have some peculiar character which prevents it from blending with them.

* Holmes's trumpet has a strong reed, and is blown by steam of about 20 lbs. pressure. He thinks low pitch is heard the furthest, and compound sounds still better. One at Dungeness has been heard in fog at five miles, when a bell of 8 cwt. was inaudible at little more than two. One larger, and an octave lower, was heard certainly at nine and a half miles. These require less steam than the whistle.

Such character must be in its pitch and in its peculiar quality of tone (*timbre*), both of which should differ as much as possible from those which contend with it. The effect of interrupted sounds should also be tested.

"This is the most important portion of the inquiry.

"C. All this is of still more moment when the air is made a discontinuous medium by the presence of fog, rain, or snow; and it is probable that the origin and quality of the sound may in such cases exert a still greater influence than in clear weather. The remarkable power of fog to deaden the report of guns has often been noticed, but it should be carefully studied for each of the three classes of signals which have been mentioned. It is also possible that the signals which are best in clear weather may not be so under these conditions.

"D. Experiments are required on the degree of accuracy with which the direction of a sound can be ascertained; and whether such estimation can be assisted by a hearing-trumpet, a tense membrane, or other acoustic aids.

"E. It is of even greater importance to try the transmission of sound through water, which seems to offer peculiar advantages, if we may judge from the few experiments which have been made by Colladon and others, some of the details of which are given in a report furnished by one of us to the British Association (a copy of which is transmitted with this). It may be expected that greater distances will be commanded, that there will be fewer disturbing causes, and that the direction will be more easily determined. Such conclusions, at least, follow from two facts observed by Colladon. A small bell struck by a hammer under water was heard easily across the Lake of Geneva, at nine miles' distance; and its sound diverged much less behind a screen than it would have done in air. These subaqueous sounds, however, do not easily pass out from water into air, being reflected at the surface of junction; and they must be listened to with a kind of hearing-tube dipped in the water. This presents little difficulty, and (at least in iron ships) the hull of the vessel may perhaps itself serve as the sound-catcher. A bell, however, is not the only nor even the best means of making these sounds. Small cartridges of powder fired under water at regular intervals would correspond to guns, and would undoubtedly be heard at very great distances. The Siren is still more promising: it is a box whose lid is made to revolve by the passage of a stream of some fluid through a number of oblique apertures, which are thus alternately opened and closed. This instrument gives under water a musical tone of extraordinary fulness and power, which could not be easily mistaken for any other sound. And, lastly, one of us (Professor Wheatstone) has found that tubes fitted with the embouchures of organ-pipes, and made to *speak* under water by a current of that fluid, produce a sound of exceeding intensity. The success of any of these subaqueous signals depends on the power of distinguishing them from sounds due to the vessel itself. In particular, the paddles or screw, and the impact of waves on the bow, must be powerful generators of submarine sounds; but it is highly probable that the character of the signal-sounds will be entirely different from them.

"If, as we hope, you feel sufficient interest in the matters above mentioned to direct such an investigation of them as may lead to practical results, we would further take the liberty of suggesting what seems to us likely to be the most effective and economical way of carrying it out, at the same time offering whatever further information we may be able to afford.

"The experiments might centre in the flag-ship at Spithead. One of its officers might probably be found who would take an interest in the research, or a supernumerary might be appointed for this special object. He should

be charged with the general control, and in particular with making the signals. These should be observed from various points, at Portsmouth and on the Isle of Wight, so disposed as to give a series of distances from two to ten miles, if possible—and so distributed that some may always have the signal *up*, others *down* the wind, which is an essential condition.

"Portland seems also to be very suitable, or perhaps Weymouth.

"Coast-guards or other local officials can probably be found at any of these stations to observe the signals; but, in any case, it is necessary that the persons engaged should be habitually on the spot, so as to profit by the occurrence of a fog without any delay.

"The process would be of this sort:—

"When the fog seems to the directing officer sufficiently thick, he sends word to the different observers of the time and nature of the intended signals; he and they then measure the fog by the means already suggested, or some equivalent.

"The signals, if fully carried out, should be—

"1. Guns.

"2. Bells, gongs, drums.

"3. Steam-whistle, blown by steam from a small boiler, and by air condensed to the same pressure (unless it be found that both sounds are equally audible). The pressures should be recorded.

"4. Two organ-pipes, one whose pitch can be varied at pleasure, the other with a reed, connected so that they can be blown together or separately.

"5. Holmes's trumpet, Daboll's, or any other which appears to deserve a trial.

"6. A Siren of 8 inches diameter, supplied with water by a hand-pump under a head of about 30 feet (which head must be recorded): by increasing the pressure, the pitch rises.

"7. An organ-pipe of variable length, to be sounded under water as the Siren.

"The chief points to be attended to in these signals are—

"1. The relative efficiency of guns of various calibre, and with varied charges of powder.

"2. Weights of bells, and force of blows, measured by the weight and fall of the hammers.

"3. In the wind instruments, the effect of varying the pressure. It is probable that each will have some appropriate force of blast which will give a maximum result.

"4. The two pipes are first to be sounded separately on the same note, to ascertain if the reed have any advantages. Then the variable one is to be gradually sharpened through a considerable range, to find what pitch is best for distance; and lastly, both sounding in unison, one is to be sharpened, so as to examine the influence of concords and discords through a large portion of the scale. They should be sounded not only continuously, but also with short interruptions.

"5. The Siren should be tried in a metallic cylinder, to learn if this will intercept its sound. If so, by making apertures in the cylinder and causing it to revolve, it may be as possible to identify such signals as revolving lights.

"Each observer, when he hears these signals, should note the time and his impression as to their distinctness. He should also try how near he can estimate their direction. For this purpose (unless he can thoroughly depend on his freedom from bias) he should be blindfolded and turned about to lose his bearings. He should also try, as above suggested, the aid of acoustic

tubes. A common speaking-trumpet will in the first instance be the most convenient. The direction and velocity of the wind should be recorded.

"The returns from each station should be sent, *without delay or comparison*, to the directing officer.

"When a series of these experiments shall have given the comparative values of the above-mentioned signals, and their ranges as found by observers at rest, the work would be incomplete unless it were extended to the conditions which must occur in practice; and it should be tried, the observer being in a steam-ship *under way, both in calm and rough weather.* The preliminary trials will have sifted out much uncertainty, and only those cases which give good promise need be examined; so that, with a moderate expenditure of money and labour, we should possess a complete collection of the facts on which this element of nautical safety must be founded.

"The money value of any one of the hundreds of ships which perish yearly through the inefficiency of the present fog-signals would far more than pay the cost of the experiments proposed; but who will price the gallant men who perish with them?

"I have the honour to be,
"Your obedient Servant,
"T. R. Robinson, *Chairman.*"

"Armagh Observatory,
May 22, 1863."

On the 6th of July, the Secretary of the Marine Department acknowledged the receipt of this letter, and informed me that "Their Lordships are in communication with the Trinity House of London on this subject, with the view of having experiments made."

On August 6th I wrote to Mr. Farrer, inquiring if any further steps had been taken; and on the 14th received an answer, enclosing a letter from the Secretary of the Trinity House, and Dr. Faraday's report referred to in it. Its substance is, "That though the Elder Brethren entertain the opinions so ably enunciated in Professor Faraday's letter, they are earnestly desirous of obtaining an elucidation of the important and comprehensive questions involved in the proposed inquiry, and will be ready to cooperate in any measures which their Lordships may desire to adopt for the attainment of that result."

I fear this implies that the Trinity House will make no great exertion for such "attainment"—the "opinions enunciated by Professor Faraday" being, in fact, that no attempt should be made by that Corporation to carry out the researches which we recommended to the Board of Trade. These opinions Dr. Faraday seems to have formed, not from any doubt of the importance of the subject, to which he bears the fullest testimony, nor from any conviction that the proposed experiments are useless or impracticable—for he does not discuss them at all,—but from a dread of the difficulty, the magnitude, and the expense of the investigation. These we believe he exaggerates; but even taking them at his estimate, we think they will not be accepted by the public as a satisfactory excuse for the inertia of this powerful body in a matter which touches so deeply, not merely the commercial interests of the nation, but even *the common instincts of humanity.*

I have not replied to the Secretary of the Board of Trade, as, before I could learn the opinions of my colleagues (to whom I at once forwarded the papers) our commission would have expired by the meeting of the Association. If it be its pleasure to reappoint us with instructions to persevere in seeking a more favourable result, I can answer for myself and the rest of the Committee that our best efforts shall be directed to fulfil our trust.

Report of the Committee appointed by the British Association on Standards of Electrical Resistance.

The Committee consists of—Professor Wheatstone, Professor Williamson, Mr. C. F. Varley, Professor Thomson, Mr. Balfour Stewart, Mr. C. W. Siemens, Dr. A. Matthiessen, Professor Maxwell, Professor Miller, Dr. Joule, Mr. Fleeming Jenkin, Dr. Esselbach, Sir C. Bright.

The Committee on Electrical Measurements, appointed in 1862, have not confined their attention to determining the best unit of electrical resistance, the point to which the duties of the Committee of 1861 were nominally restricted, but have viewed this comparatively limited question as one part only of the much larger subject of general electrical measurement. The Committee, after mature consideration, are of opinion that the system of so-called absolute electrical units, based on purely mechanical measurements, is not only the best system yet proposed, but is the only one consistent with our present knowledge both of the relations existing between the various electrical phenomena and of the connexion between these and the fundamental measurements of time, space, and mass. The only hesitation felt by the Committee was caused by doubts as to the degree of accuracy with which this admirable system could be or had been reduced to practice.

The measurement of voltaic currents, electromotive force, and quantity would offer little difficulty, provided only electrical resistance could be measured in absolute units, and for this purpose it would be sufficient that the resistance of a single standard conductor should be so determined, since copies of this standard could be multiplied at will with any desired precision, and from comparison with these copies the absolute resistance of any circuit whatever could be obtained by methods requiring comparatively little skill and well known to all electricians. The practical adoption of the absolute system was felt therefore to depend on the accuracy with which the absolute resistance of some one standard conductor could be measured; and while doubts existed on this point, it was thought premature to make any extended experiments on the application of the absolute system to voltaic currents, electromotive force, or quantity. The Committee are happy to report that these doubts have been dispelled by the success of the experiments, made for the Committee by Professor J. Clerk Maxwell, Mr. Balfour Stewart, and Mr. Fleeming Jenkin, according to the method devised by Professor W. Thomson. These experiments have been actively prosecuted at King's College for the last five months with continually increasing success, as, one by one, successive mechanical and electrical improvements have been introduced, and the various sources of error discovered and eliminated.

The Sub-Committee are confident that considerably greater accuracy can yet be obtained by the further removal of slight defects, the importance of which only became apparent when the main difficulties had been overcome. In order, therefore, to secure the best attainable result, and still further to test the accuracy and concordance of the experiments before taking any irrevocable step, the Committee have decided not to issue standard coils at the present Meeting; but the results already obtained leave no room for doubt that the absolute system may be adopted, and that the final standard of resistance may be constructed without any serious delay. Over-haste might eventually entail corrections as inconvenient as those which would follow an arbitrary and unscientific choice of units, and the very experiments made by the Sub-Committee prove that the hesitation of many to adopt the absolute

units as hitherto determined was well founded. It is certain that resistance-coils purporting to have been constructed from previous absolute determinations do not agree one with another within 7, 8, or even 12 per cent.

Before further alluding to the results obtained by the Sub-Committee, it is desirable that the experiments themselves should be understood, and to this end the Committee have thought fit that a full explanation of the meaning of absolute measurement, and of the principles by which absolute electrical units are determined, should form part of the present Report, especially as the only information on the subject now extant is scattered in detached papers by Weber, Thomson, Helmholtz, and others, requiring considerable labour to collect and understand. In order to make this account as clear as possible, it has been thought best to disregard entirely the chronological order of the discoveries and writings on which the absolute system is founded, and this has rendered it very difficult to refer to the original source of each statement or conclusion. In the Appendix (C.) this want is, it is hoped, remedied.

The word "absolute" in the present sense is used as opposed to the word "relative," and by no means implies that the measurement is accurately made, or that the unit employed is of perfect construction; in other words, it does not mean that the measurements or units are absolutely correct, but only that the measurement, instead of being a simple comparison with an arbitrary quantity of the same kind as that measured, is made by reference to certain fundamental units of another kind treated as postulates. An example will make this clearer. When the power exerted by an engine is expressed as equal to the power of so many horses, the measurement is not what is called absolute; it is simply the comparison of one power with another arbitrarily selected, without reference to units of space, mass, or time, although these ideas are necessarily involved in any idea of work. Nor would this measurement be at all more absolute if some particular horse could be found who was always in exactly the same condition and could do exactly the same quantity of work in an hour at all times. The foot-pound, on the other hand, is one derived unit of work, and the power of an engine when expressed in foot-pounds is measured in a kind of absolute measurement, *i. e.* not by reference to another source of power, such as a horse or a man, but by reference to the units of weight and length simply—units which have been long in general use, and may be treated as fundamental. In this illustration, chosen for its simplicity, the unit of force is assumed as fundamental, and as equal to that exerted by gravitation on the unit mass; but this force is itself arbitrarily chosen, and is inconstant, depending on the latitude of the place of the experiment.

In true absolute measurement the unit of force is defined as the force capable of producing the unit velocity in the unit of mass when it has acted on it for the unit of time. Hence this force acting through the unit of space performs the absolute unit of work. In these two definitions, time, mass, and space are alone involved, and the units in which these are measured, *i. e.* the second, gramme, and metre, will alone, in what follows, be considered as fundamental units. Still simpler examples of absolute and non-absolute measurements may be taken from the standards of capacity. The gallon is an arbitrary or non-absolute unit. The cubic foot and the litre or cubic decimetre are absolute units. In fine, the word absolute is intended to convey the idea that the natural connexion between one kind of magnitude and another has been attended to, and that all the units form part of a coherent system. It appears probable that the name of "derived units" would more readily convey the required idea than the word "absolute," or the name of mechanical units might

have been adopted; but when a word has once been generally accepted, it is undesirable to introduce a new word to express the same idea. The object or use of the absolute system of units may be expressed by saying that it avoids useless coefficients in passing from one kind of measurement to another. Thus, in calculating the contents of a tank, if the dimensions are in feet, the cubic contents are given in cubic feet, without the introduction of any coefficient or divisor; but to obtain the contents in gallons, the divisor 6·25 is required. If the power of an engine is to be deduced from the pressure on the piston and its speed, it is given in foot-pounds or metre-kilogrammes per second by a simple multiplication; to obtain it in horse-power, the coefficients 33,000 or 550 must be used. No doubt all the natural relations between the various magnitudes to be measured may be expressed and made use of, however arbitrary and incoherent the units may be. Nevertheless the introduction of the numerous factors then required in every calculation is a very serious annoyance, and moreover, where the relations between various kinds of measurement are not immediately apparent, the use of the coherent or absolute system will lead much more rapidly to a general knowledge of these relations than the mere publication of formulæ.

The absolute system is, however, not only the best practical system, but it is the only rational system. Every one will readily perceive the absurdity of attempting to teach geometry with a unit of capacity so defined that the contents of a cube should be $6\frac{1}{4}$ times the arithmetical cube of one side, or with a unit of surface of such dimensions that the surface of a rectangle would be equal to 0·000023 times the product of its sides; but geometry so taught would not be one whit more absurd than the science of electricity would become unless the absolute system of units were adopted.

In determining the unit of electrical resistance and the other electrical units, we must simply follow the natural relation existing between the various electrical quantities, and between these and the fundamental units of time, mass, and space. The electrical phenomena susceptible of measurement are four in number—current, electromotive force, resistance, and quantity. The definitions of these need not now be given, but will be found in the Appendix (C. 14, 15, 16, and 17). Their relations one to another are extremely simple, and may be expressed by two equations.

First, by Ohm's law, experimentally determined, we have the equation

$$C=\frac{E}{R}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where C=current, E=electromotive force, and R=resistance. From this formula it follows that the unit electromotive force must produce the unit current in a circuit of unit resistance; for if units were chosen bearing any other relation to each other, C would be equal to $x\frac{E}{R}$, where x would be a useless and absurd factor, complicating all calculation, and confusing the very simple conception of the relation established by Ohm's law.

Secondly, it has been experimentally proved by Dr. Faraday that the statical quantity of electricity conveyed by any given current is simply proportional to the strength of the current, whether electromagnetically or electrochemically measured, and to the time during which it flows; hence, in mathematical language, we have the equation

$$Q=Ct, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where t=time, and Q=quantity. From this equation it follows that the unit of quantity must be the quantity conveyed by the unit current in the unit of

time; otherwise we should have $Q=yCt$, where y would be a second useless and absurd coefficient. From equations (1) and (2) it follows that only two of the electrical units could be arbitrarily chosen, even if the natural relation between electrical and mechanical measurements were disregarded. Thus if the electromotive force of a Daniell's cell were taken as the unit of electromotive force, and the resistance of a metre of mercury of one millimetre section at 0° were taken as the unit of resistance, it would follow from equations (1) and (2) that the unit of current must be that which would be produced by the Daniell's cell in a circuit of the above resistance, and the unit of quantity would be the quantity conveyed by that current in a second of time. Such a system would be coherent; and if all mechanical, chemical, and thermal effects produced by electricity could be neglected, such a system might perhaps be called absolute. But all our knowledge of electricity is derived from the mechanical, chemical, and thermal effects which it produces, and these effects cannot be ignored in a true absolute system. Chemical and thermal effects are, however, now all measured by reference to the mechanical unit of work; and therefore, in forming a coherent electrical system, the chemical and thermal effects may be neglected, and it is only necessary to attend to the connexion between electrical magnitudes and the mechanical units. What, then, are the mechanical effects observed in connexion with electricity? First, it has been proved that whenever a current flows through any circuit it performs work, or produces heat or chemical action equivalent to work. This work or its equivalent was experimentally proved by Dr. Joule to be directly proportional to the square of the current, to the time during which it acts, and to the resistance of the circuit; and it depends on these magnitudes only. In mathematical language this is expressed by the equation $W=C^2 Rt$, ... (3), where W=the work equivalent to all the effects produced in the circuit, and the other letters retain their previous signification. This is the third fundamental equation affecting the four electrical quantities, and represents the most important connexion between them and the mechanical units. From equation (3) it follows (unless another absurd coefficient be introduced) that the unit current flowing for a unit of time through a circuit of unit resistance will perform a unit of work or its equivalent. If every relation existing between electrical and mechanical measurements were expressed by the three fundamental equations now given, they would still leave the series of units undefined, and one unit might be arbitrarily chosen from which the three other units would be deduced by the three equations; but these three equations by no means exhaust the natural relations between mechanical and electrical measurements. For instance, it is observed that two equal and similar quantities of electricity collected in two points repel one another with a force (F) directly proportional to the quantity Q, and inversely to the square of the distance (d) between the points. This gives the equation

$$F=\frac{Q}{d^2}; \quad . . . . (4)$$

from which it would follow that the unit quantity should be that which at a unit distance repels a similar and equal quantity with unit force. The four equations now given are sufficient to measure all electrical phenomena by reference to time, mass, and space only, or, in other words, to determine the four electrical units by reference to mechanical units. Equation (4) at once determines the unit of quantity, which, by equation (2), determines the unit current; the unit of resistance is then determined by equation (3), and the unit electromotive force by equation (1). Here, then, is one absolute or coherent

system, starting from an effect produced by electricity when at rest. The units based on these four equations are precisely those called by Weber electrostatical units, although it may be observed that he chose those units without reference to what is here called the third fundamental equation, or, in other words, without reference to the idea of work, introduced into the system by Thomson and Helmholtz*.

The four equations are sufficient to determine the four units, and into this system no new relation can be introduced. The first three equations may, however, be retained, and a distinct absolute system established by substituting some other relation between electrical and mechanical magnitudes than is expressed in equation (4); and, indeed, the electrostatical system just defined is not that which will be found most generally useful. It is based on a statical phenomenon, whereas at present the chief applications of electricity are dynamic, depending on electricity in motion, or on voltaic currents with their accompanying electromagnetic effects. Now the force exerted on the pole of a magnet by a current in its neighbourhood is a purely mechanical phenomenon. This force (f) is proportional to the magnetic strength (m) of the pole of the magnet, and to the strength of the current C; and if the conductor be at all points equidistant from the pole, or, in other words, be bent in a circle of the radius k round the pole, the force is proportional to the length of the conductor (L): it is also inversely proportional to the square of the distance (k) of the pole from the conductor, and is affected by no other circumstances than those named. Hence we have

$$f=\frac{\mathrm{CL}m}{k^2}. \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

From this equation it follows that the unit length of the unit current must produce the unit force on a unit pole at the unit distance. If the equations (1), (2), (3), and (5) are adopted as fundamental, they give a distinct absolute system of units, called by Weber the electromagnetic units. Equations (4) and (5) are incompatible one with another, if equation (2) be considered fundamental; but the electromagnetic units have a constant and natural relation to the electrostatic units. It will be seen that in the fundamental equation (5) of the electromagnetic system, besides the measurements of time, space, and mass, alone entering into the other equations, a fourth measurement (m) of a magnetic pole is required; but this measurement is in itself made in terms of the mechanical units, for the unit pole is simply that which repels another equal pole at unit distance with unit force. Thus in the electromagnetic as in the electrostatic system all measurements are ultimately referred to the fundamental units of time, space, and mass. The electromagnetic units are found much the more convenient when dealing, as we have now chiefly occasion to do, with electromagnetic phenomena.

The relations of the electromagnetic units one to another and to the mechanical units may be summed up as follows:—The unit current conveys a unit quantity of electricity through the circuit in a unit of time. The unit current in a conductor of unit resistance produces an effect equivalent to the unit of work in the unit of time. The unit current will be produced in a circuit of unit resistance by the unit electromotive force. The unit current flowing through a conductor of unit length will exert the unit force on a unit pole at a unit distance. (In the electrostatic system all the above propositions hold good except the last, for which the following must be substituted:—the unit quantity of electricity will repel a similar quantity at the unit distance with a unit force.)

* *Vide* Appendix C. § 31.

It remains to be explained how electrical measurements can be practically made in electromagnetic units. Of all the magnitudes, currents are the most easily measured, provided the horizontal force (H) of the earth's magnetism be known. Let a length (L) of wire be wound so as to form a circular coil of small section as compared with its radius (k).

Let a short magnet be hung in the centre of the coil placed in the magnetic meridian, as in the ordinary tangent galvanometer, and let the deflection produced by the current C be called d, then it is easily* proved from the fundamental equation (5) that

$$C=\frac{Hk^2}{L}\tan d. \quad \ldots \ldots \ldots \ldots \ldots \quad (6)$$

Thus, where the value of H is known, a tangent galvanometer only is required to determine the magnitude of a current in electromagnetic absolute measurement, although neither the resistance of the circuit nor the electromotive force producing the current may be known. The measurement of quantity can be obtained from that of a current by a make-and-break apparatus, or "Wippe," in a well-known manner, or by measuring the swing of a galvanometer needle when a single instantaneous discharge is allowed to pass through it (Appendix C. § 25). If, therefore, we could measure resistance in absolute measure, the whole system of practical absolute measurement would be complete, since, when the current and resistance are known, equation (1) (Ohm's law) directly gives the electromotive force producing the current. The object of the experiments of the Sub-Committee (made at King's College, by the kind permission of the Principal) was therefore to determine the resistance of a certain piece of wire in the absolute system, in order from this one careful determination to construct the material representative of the absolute unit with which all other resistances would be compared by well-known methods.

There are several means by which the absolute resistance of a wire can be measured. Starting from equation (3), Professor Thomson, in 1851, determined the absolute resistance of a wire by means of Dr. Joule's experimental measurement of the heat developed in the wire by a current †; and by this method he obtained a result which agrees within about 5 per cent. with our latest experiments. This method is the simplest of all, so far as the mental conception is concerned, and is probably susceptible of very considerable accuracy.

Indirect methods depending on the electromotive force induced in a wire moving across a magnetic field have, however, now been more accurately applied; but, before describing these methods, it will be necessary to point

* The resultant electromagnetic force (f) exerted at the centre of the coil by a current (C) will, by equation (5), be $f=\frac{CL}{k^2}$, and the short magnet hung in the centre will experience a couple acting in a direction perpendicular to the plane of the coil equal to $\frac{CLml}{k^2}$, where ml = the product of the strength of one of the poles into the length of the magnet, or, in other words, its magnetic moment. The strength of the couple acting perpendicularly to the axis of the magnet, when it has deflected to an angle d under the influence of the current, will be $\cos d\,\frac{CLml}{k^2}$, at the same time the equal and opposite couple exerted on the magnet by the earth's magnetism will be $\sin d\,Hml$, hence

$$C=\frac{Hk^2}{L}\times\frac{\sin d}{\cos d}=\frac{Hk^2}{L}\tan d.$$

† Phil. Mag. vol. ii. Ser. 4, 1851, p. 551.

out the connexion between the electromotive force induced in the above manner and the fundamental equations adopted for the absolute system. The exact sense in which the terms are employed is defined in the accompanying foot-note, along with some simple corollaries from those definitions *.

A current (C) in a straight conductor of length (L) crossing the lines of force of a magnetic field of the intensity (S) at right angles will experience the same force (f) as if all the points of the conductor were at the unit distance from a pole of the strength (S). The force in this case exerted on the magnet is, by equation (5), equal to SLC, and, conversely, an equal force is exerted by the magnet on the current. Hence we have equation (7), expressing the value of the force (f) exerted on a current crossing a magnetic field at right angles,

$$f=\text{SLC}. \qquad (7)$$

Let us imagine this straight conductor to have its two ends resting on two conducting rails of large section in connexion with the earth, and let the whole sensible resistance (R) of the circuit thus formed be constant for all positions of the conductor. Let us further imagine the rails so placed that when the conductor slips along them it moves perpendicularly to the magnetic lines of force and to its own length. By experiment we know that when the conductor is moved along the rails cutting these lines of force, a current will be developed in the circuit, and that the action of the magnetic force on this current will cause a resistance (f) to the motion (due to electromagnetic causes only); and, by equation (7), we find that this resistance $f=\text{SLC}$.

Let the motion be uniform, and its velocity be called V; and let the work done in the unit of time in overcoming the resistance to motion due to electromagnetic causes be called W; then $\text{W}=\text{VSLC}$. But this force produces

* *Definition* 1.—A magnetic field is any space in the neighbourhood of a magnet.

Definition 2.—The unit magnetic pole is that which, at a unit distance from a similar pole, is repelled with unit force.

Definition 3.—The intensity of a magnetic field at any point is equal to the force which the unit pole would experience at that point.

Corollary 1.—A pole of given strength (S) will produce a magnetic field which (if uninfluenced by other magnetic forces) will at the unit distance from the pole be of the intensity S, *i. e.* numerically equal to the strength of the pole; for, at that distance, the force exerted on a unit pole would, by def. 2, be equal to S, and hence, by def. 3, the intensity of the magnetic field at that point would be equal to S.

Definition 4.—The direction of the force in the field is the direction in which any pole is urged by the magnetism of the field; this is the direction which a short-balanced, freely suspended magnet would assume.

Remark.—The properties of a magnetic field, as shown by Dr. Faraday, may be conveniently and accurately conceived as represented by *lines* of force (each line representing a force of constant intensity). The direction of the lines will indicate the direction of the force at all points; and the number of lines which pass through the unit area of cross section will represent the magnetic intensity of the field resolved perpendicularly to that area.

Definition 5.—A uniform magnetic field is one in which the intensity is equal throughout, and hence, as demonstrated by Professor W. Thomson, the lines of force parallel.

Example.—The earth is a great magnet. The instrument-room, where experiments are tried, is a magnetic field. The dipping-needle is an instrument by which the direction of the lines of force is found. The intensity of the field is found by a method described in the 'Admiralty Manual,' 3rd edit., article "Terrestrial Magnetism." The number of lines of force passing through the unit of area perpendicularly to the dipping-needle in the room must be conceived as proportional to this intensity, and the direction to correspond with that of the dipping-needle. The magnitude and direction of the earth's force at a point are generally expressed by resolving it into two components, one horizontal and the other vertical. The mean horizontal component in England for 1862 was at Kew = 3·8154 British units, or 1·7592 metrical; *i. e.* a unit pole weighing one gramme, and free to move in a horizontal plane, would, under the action of the earth's horizontal force, acquire, at the end of a second, a velocity equal to 1·7592 metres per second. (*Vide* also Appendix C. § 5 to 12.)

no other effect than the current, and the work done by the current must therefore be $=W$, or equivalent to that done in moving the conductor against the force f; but, by equation (3), $W=C^2R$, and hence

$$R=\frac{VSL}{C} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

It has already been shown that C and S can be obtained in absolute measure; hence the second member of equation (8) contains no unknown quantities, and, by the experiment described, the absolute resistance (R) of a wire might be determined. One curious consequence of these considerations is, that the resistance of a conductor in absolute measure is really expressed by a velocity; for, by equation (8), when $SL=C$ we have $R=V$, that is to say, the resistance of a conductor may be expressed or defined as equal to the velocity with which it must move, if placed in the conditions described, in order to generate a current equal to the product of the length of the conductor into the intensity of the magnetic field; or more simply, the resistance of a circuit is the velocity with which a conductor of unit length must move across a magnetic field of unit intensity in order to generate a unit current in the circuit. Moreover it can be shown that this velocity is independent of the magnitude of the fundamental units on which the expression of the magnetic intensity of the field or strength of the current is based, and hence that electrical resistance really is measured by an absolute velocity in nature, quite independently of the units of time and space in which it is expressed. (Appendix C, § 39.) By equation (8) we have $C=\frac{VSL}{R}$, but by equation (1) $C=\frac{E}{R}$, hence

$$E=VSL; \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

that is to say, the electromotive force produced between two ends of a straight conductor moved perpendicularly to its own length and to the lines of force of a magnetic field is equal to the product of the intensity of the field into the length of the conductor and the velocity of the motion; or, more simply, the unit length of a conductor moving with unit velocity perpendicularly across the lines of force of a magnetic field will produce a unit electromotive force (or difference of potential) between its two ends. This was by Weber made a fundamental equation, in place of equation (3), first shown by Thomson and Helmholtz to be consistent with Weber's electromagnetic equation. These simple and beautiful relations between inductive effects and the simple voltaic effects first described are well adapted to show the rational and coherent character of the absolute system.

The experiment last described, as a method of finding the absolute resistance of a conductor by measuring the velocity of motion of a straight wire, would be barely practicable; but it will be easily understood that we can, by calculation, pass from this simple case to the more complex case of a circular coil of known dimensions revolving with known velocity about an axis in a magnetic field of known intensity. Weber, from these elements, determined the absolute resistance of many wires; but this method requires that the intensity of the magnetic field be known; and the determination of this element is laborious, while its value, for the earth at least, is very inconstant. A method due to Professor Thomson, by which a knowledge of this element is rendered unnecessary, has therefore been adopted in the experiments of the Sub-Committee at King's College. In this plan a small magnet, screened from the effect of the air, is hung at the centre of a revolving coil, which is divided into two parts to allow the suspending fibre to pass freely.

By calculation it can be shown that when the coil revolves round a vertical

axis, the couple exerted on a magnetic needle of the moment ml, when deflected to the angle d, will be $\frac{L^2 VH}{4k^2 R} ml \cos d$.

The equal and opposite couple caused by the earth's magnetism will be $Hml \sin d$. Hence

$$\tan d = \frac{L^2 V}{4k^2 R}$$

or

$$R = \frac{L^2 V}{4k^2 \tan d}, \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

an equation from which the earth's magnetic force and the moment of the suspended magnet have been eliminated, and by which the absolute resistance (R) can be calculated in terms of the length, L, the velocity, V, the radius, k, and the deflection, d. The resistance thus calculated is expressed in electromagnetic absolute units, because equation (10) is a simple consequence of equations (1), (3), and (5)—fundamental equations in the electromagnetic system. The essence of Professor Thomson's method consists in substituting, by aid of the laws of electromagnetic induction, the measurements of a velocity and a deflection for the more complex and therefore less accurate measurements of work and force required in the simple fundamental equations. But, however simple in theory the method may be, the practical determination of the absolute resistance of a conductor by its means required great care and very numerous precautions,—some of an obvious character, while the need of others only became apparent during the course of the experiments.

The apparatus consisted of two circular coils of copper wire, about one foot in diameter, placed side by side, and connected in series; these coils revolved round a vertical axis, and were driven by a belt from a hand-winch, fitted with Huyghens' gear to produce a sensibly constant driving-power. A small magnet, with a mirror attached, was hung in the centre of the two coils, and the deflections of this magnet were read by a telescope from the reflection of a scale in the mirror. A frictional governor controlled the speed of the revolving coil. The details and a drawing of the apparatus are given in Appendix D. and Plate VI.; but a short account may fitly be given here of the points of chief practical importance, the difficulties encountered, and the improvements still desirable.

It is essential that the dimensions of the coil be very accurately known, that the axis round which it revolves should be truly vertical, and that, except in the coil itself, no currents affecting the position of the magnet be induced in any part of the apparatus. To measure the angular deflection the distance of the scale from the mirror is required, and the scale must be truly parallel to the mirror when the magnet is undeflected, or, in other words, when the coil is at rest. All these conditions were fulfilled without difficulty; but the scale by the reflection of which the deflections were measured was, towards the end of the experiments, found not to be very accurately divided; and although a correction for this inaccuracy has been applied in the calculations, an improvement can in future experiments be effected by the use of a more perfect scale. The magnet was suspended by a single silk fibre, eight feet long, inside a wooden case, and by suitable adjustments was brought very carefully to the centre of the coils. The whole suspended system was so screened from currents of air, and so well protected from vibration, that when the coil revolved at its full speed of 350 revolutions per minute, the reflection in the mirror was as clear and undisturbed as when the coil was at rest. The torsion of the long fibre was determined by experiment, and the slight

necessary corrections applied in the calculations. The Huyghens' gearing for the driving hand-winch was somewhat roughly constructed, and could certainly be improved; nevertheless there was little difficulty in maintaining a sensibly constant driving-power for twenty minutes at a time. The speed of the coil was controlled by a frictional governor of novel form, designed by Mr. Jenkin for another purpose, and lent for the experiments in question. The action of this governor, combined with that of the driving-gear, was such that in many experiments the oscillations in deflection due to a change of speed were not so great as those due to the passage of steamers in the river when all parts of the apparatus were at rest; so that the deflections during twenty minutes could be quite as accurately observed as the slightly imperfect zero-point from which they were measured. Still better results are expected with a larger governor, made specially for the apparatus, on the joint plans of Professor Thomson and Mr. Jenkin. The oscillations produced by the passage of steamers on the Thames at no great distance from the place of experiments were of very sensible magnitude; and although by carefully observing the limit of every oscillation during every experiment the error due to this cause was in great part eliminated, it is desirable that any future experiments should be conducted in some spot free from all local magnetic disturbance.

The speed of the coil was determined by observing on a chronometer the instant at which a small gong was struck by a detent released once in every hundred revolutions. Mr. Balfour Stewart's skill in this kind of observation enabled him thus to determine the velocity with great accuracy, especially as the observations frequently lasted for twenty minutes without material alteration in the speed.

Some error was apprehended in the necessary measurement of the length of the copper wire used, owing to the extension that would be caused by the strain usually required to straighten the wire. This really serious difficulty was eluded almost by accident, in a manner amusing from its simplicity. At the conclusion of the experiments, the wire to be measured was uncoiled in the Museum at King's College and lay in awkward bends on the planked floor. The straight planks formed an obvious contrast to the crooked wire, and a joint between the planks was found where the opening was just sufficient to hold the wire when pushed into this little groove. Held in this way, the wire when measured was quite straight, and yet was never stretched.

No other measurements than those already described are required by the simple theory; but this theory, as hitherto stated, stands in need of various slight corrections. The currents induced by the earth's magnetism are modified by the currents induced from the little suspended magnet, and also by the induction of the coil on itself. The force deflecting the magnet is also modified by the lateral distance of the coils from the vertical axis. An elaborate analysis of the corrections required on these grounds was made by Professor Maxwell (Appendix D.); and to allow of these corrections, the moment of the suspended magnet was measured, and the position of every turn of the copper coil carefully observed. An experimental determination of the induction of the coil on itself, by a method due to Professor Maxwell, agreed with the calculated correction within one quarter per cent.

The resistance of the copper coil measured by these laborious experiments varied each day, and during each day, according to the temperature; and, moreover, this temperature could at no time be determined with sufficient accuracy. It was therefore intended that at each experiment a small German-silver coil, at a known temperature, should have been prepared exactly equal in resistance to the copper coil during that experiment, and these small coils

were to have been kept as permanent records of the resistance of the copper coil on each occasion; but this resistance was found to vary so rapidly that the little copies could not be accurately adjusted with sufficient rapidity, and the resistance of the copper coil was therefore simply measured at the beginning and end of each experiment, in terms of an arbitrary unit. This proportional measurement was made with rapidity and precision by a new method, which, it is believed, is superior to the usual plan depending on the division or calibration of a comparatively short wire in the Wheatstone balance. (Appendix D. Part II.)

One unforeseen difficulty was caused by the change of direction of the earth's magnetic force during each experiment. Our method is indeed independent of the intensity of the earth's magnetism, but depends essentially on its direction, since it depends on the value of a deflection from the magnetic meridian. When this source of error was discovered by the continual and gradual change of zero observed, the absolute time of each experiment was noted, and a continuous correction obtained from the contemporaneous records at Kew, which agreed closely with the total changes observed at the beginning and end of each experiment. As the change of zero frequently reached three or four divisions in the course of the day, and as the whole deflection seldom exceeded 300 divisions, the importance of this correction is apparent.

The presence of stationary masses of iron does not affect the experiments injuriously, so long as the uniformity of the magnetic field in which the coil revolves is undisturbed—a point carefully tested before the experiments began; but a change in the position of iron in the neighbourhood during any experiment produces a corresponding error in the result, and the serious effect of moving very small masses of iron at a great distance from the coil was only fully appreciated in the later experiments.

When it is considered that the method described is the simplest known, the discrepancy between the few determinations hitherto made in absolute measurement will cause no surprise. The time, labour, and money required could hardly be expected to be given by any one person, and in researches of this kind the value of the cooperation secured by the committees of the Association is especially evident.

The absolute unit of the Sub-Committee is about eight per cent. larger than the unit as derived from a German-silver coil lately measured by Professor Weber. It is about six and a half per cent. larger than the unit as derived from a value published by Professor Weber of Dr. Siemens's mercury units. It is about five per cent. smaller than the unit as derived from coils issued by Professor Thomson in 1858, based on Jacobi's standard and a previous determination by Professor Weber. It is about five per cent. smaller than Thomson's determination from Joule's silver wire. It agrees most closely with an old determination of a copper standard made by Weber for Professor Thomson, which it exceeds by only a very small fraction.

The experiments of the Sub-Committee agree much better than the above one with another. Owing to the gradual improvement in the method and apparatus, the experiments of the last three days are alone considered satisfactory. On the first day the maximum deviation in six distinct experiments from their mean result was 2·4 per cent. On the second day the maximum deviation in four experiments from their mean was 1·3 per cent. On the third day the maximum deviation in five experiments from their mean was 1·15 per cent. The maximum deviation in the means of the three days' experiments from the mean of the whole is only four-tenths per cent.

These results are not unsatisfactory, and are perhaps more accurate than

any measurement yet made of the relative values of heat and work—a measurement corresponding to a great extent in its nature with that undertaken by the Committee. Nevertheless, considering the discrepancy of the various independent results, the Committee are of opinion that it is essential that the results of the Sub-Committee should be checked by a fresh series of experiments with a new coil in a distinct place, when every separate measurement will necessarily be repeated. The Sub-Committee especially urge the repetition of the experiments, as with the improvements already enumerated, and other minor alterations, they confidently expect a considerably closer approximation to the absolute unit than they have hitherto obtained. It will be well here to remark that, according to the resolution of the Committee of 1861, the coils, when issued, will not be called absolute units, but the units of the British Association; so that any subsequent improvement in experimental absolute measurement will not entail a change in the standard, but only a trifling correction in those calculations which involve the correlation of the physical forces.

It is now time to leave the question of absolute measurement and pass to some of the other points under the consideration of the Committee. Dr. Matthiessen has, by careful experiment, proved the permanence for a year at least of the electrical resistance of certain wires; but he has detected a change in others, due, apparently, to the influence of time. Certain specimens of silver, gold, and copper have varied; but other specimens of the same metals have remained constant. All the specimens of platinum and gold-silver alloy have remained constant, and all the specimens of German silver have changed considerably. It is proposed to continue and extend these experiments, and it is much to be hoped that the defect observed in the German silver tested will not be found common to all the varieties of this alloy, in other respects so well adapted for the construction of resistance-coils. Dr. Matthiessen found no difference in the resistance of wires of any of the above metals before and after the passage of a powerful current transmitted through them continually for a fortnight. The details of these experiments are given in Appendix A. Dr. Matthiessen has also continued his experiments with the object of finding an alloy with a minimum variation of resistance due to change of temperature, but has been unable to produce a wire superior in this respect to the silver-platinum alloy mentioned in Appendix A. of the Report of last year, as decreasing in conducting power 3·1 per cent. between 100° and 0° Centigrade. German silver was found to decrease under the same circumstances 4·4 per cent.

The valuable experiments by Mr. Sabine, for Dr. Werner Siemens of Berlin, on the reproduction of standards by means of mercury, although not undertaken for the Committee, yet bear so directly on the subject before them that the results cannot be allowed to pass unmentioned. Dr. Siemens has conclusively proved that he can, in his laboratory, reproduce a standard by means of mercury with an error of less than 0·05 per cent. This admirable result, while it seriously affects the question of the best material for the construction and reproduction of the standard, leaves, of course, the question of the best magnitude for the standard quite untouched. Dr. Matthiessen thinks that several of the solid metals are equally fitted for the purposes of reproduction, and, if aided by the Association, is disposed to put his conviction to experimental proof. It is especially desirable that the various methods proposed should be tested by the concordance of the results obtained from a number of independent observers.

With reference to the construction of the material standard, it is proposed

that the British Association units shall be represented by several equal standards made of the different metals, which, so far as our limited experience goes, show the greatest signs of constancy. Two at least of those standards would be made of mercury, in the manner proposed by Dr. Siemens. The permanent agreement between several of these standards would afford the strongest possible proof of their constancy.

Passing to other electrical measurements, the Committee have to report that Professor W. Thomson has successfully constructed a material standard gauge by which electromotive force or difference of potentials can be directly measured. This instrument is founded on a measurement of the electrical attraction exerted on a small moveable portion of a large conducting-plane by another large parallel plane fixed at a constant distance, and electrified to a different potential. The force exerted is ultimately measured by the torsion of a platinum wire; but the difference of potential corresponding to any one gauge is simply indicated by the motion of an index to a sighted position. If the planes are brought sufficiently close, with a given torsion in the platinum wire, the moveable piece will be in a condition of unstable equilibrium when its index is in the sighted position, but if moved to a greater distance the equilibrium will be stable; hence, by a correct choice of the distance between the two planes, or initial torsion in the platinum wire, as compared with the difference of potential to be measured, any required delicacy of indication is obtained. The constancy of the gauge, like that of all standards, depends simply on the constancy of the materials of which it is constructed, and there is no reason to apprehend any special difficulty in the present case.

Professor Thomson has also on the same principle constructed an electrometer in which the distance between the parallel planes is made variable, and is adjusted by a micrometer-screw. The plane conductor, of which the small moveable index forms part, is in this instrument permanently maintained at a high potential by connexion with the inner coating of a Leyden jar, and the other plane is connected with the body to be tested. Calculation, confirmed by experiment, shows that in these instruments the difference of potentials between any two bodies, successively tested, is directly proportional to the difference of the distances between the parallel planes required in each case to bring the index to its sighted position. This difference of distance is the same whatever be the charge of the Leyden jar, provided only it remains constant during the comparison of the two bodies. With this limitation, the indications of the instrument may be called independent of the charge of the Leyden jar. There can be little doubt that gauges of electromotive force and electrometers, fulfilling the above conditions, will shortly become as necessary to all practical electricians as standards of resistance and sets of resistance-coils.

No progress has been made in the measurement of currents, and much remains to be done in this respect. The method already described, depending on the use of a tangent galvanometer, requires a knowledge of the horizontal force of the earth's magnetism, and is, therefore, in most cases beyond the reach of observers where greater accuracy is required than can be obtained by taking their value from the scientific almanacs. Next year it is hoped that this want may be remedied, and the present Report may fitly conclude by the enumeration of objects to be pursued by the Committee, if reappointed at the present Meeting:—

1st. The experiments on the determination of the absolute unit of resistance will be continued.

2nd. Immediately on the conclusion of these experiments, equal standards, constructed of such metals as promise the greatest constancy, will be deposited at Kew, where the permanence of their equality will be rigorously tested.

3rd. Unit resistance-coils of the best known construction will be issued to the public.

4th. The experiments already begun on the permanence of the electrical resistance of wires and alloys under various circumstances will be continued and extended.

5th. The experiments on the reproduction of standards by chemical means will be continued.

6th. Experiments on the best construction of gauges of electromotive force or difference of potential, and on electrometers, will be continued.

7th. A standard galvanometer, for the measurement of currents in absolute measure, will be constructed, and electro-dynamometers for the same purpose compared with the standard instrument, and issued to the public.

8th. Experiments on the ratio between the electrostatic units and the electromagnetic units will be undertaken.

9th. Experiments will be made on the development of heat in conductors of known absolute resistance with currents of known absolute magnitude. The results of this experiment will give, by equation (3), a new and very accurate determination of the mechanical value of the unit of heat.

The conclusion of the experiments on absolute resistance, and the adoption of the absolute system as the basis of all electrical measurement, will, it is hoped, allow considerable progress to be made in most of these researches.

Appendix A.—*On the Electrical Permanency of Metals and Alloys.* *By* A. Matthiessen, *F.R.S.*

The following are the results obtained with the metals and alloys described in Appendix B. of the Report on Standards of Electrical Resistance by your Committee:—

The wires to be experimented on were—

1. Silver: hard drawn .... 2. Silver: annealed	Cut from the same piece; pure.
3. Silver: hard-drawn .... 4. Silver: annealed	Cut from the same piece, but different from 1 and 2; pure.
5. Copper: hard-drawn ...... 6. Copper: annealed..........	Cut from the same piece; pure.
7. Copper: hard-drawn ...... 8. Copper: annealed..........	Cut from the same piece, but different from 5 and 6; pure.
9. Gold: hard-drawn .... 10. Gold: annealed	Cut from the same piece; pure.
11. Gold: hard-drawn .... 12. Gold: annealed	Cut from the same piece, but different from 9 and 10; pure.
13. Platinum: hard-drawn .... 14. Platinum: hard-drawn	Cut from the same piece; commercial.
15. Gold-silver alloy: hard-drawn 16. Gold-silver alloy: hard-drawn	Cut from same piece. Made by Messrs. Johnson and Matthey.
17. German silver: annealed.... 18. German silver: annealed.... 19. German silver: annealed....	Cut from the same piece. No. 19 arranged with longer connectors, and used as normal wire with which the rest were compared.

These were first tested on May 9th, 1862, and at intervals between that

date and June 14th, 1863, when they were last tested. During the time when not used, they were hung up in a room where in the winter a fire was kept all day, so that the temperature may have varied at times some 10 or 12 degrees in the twenty-four hours.

The following Table contains the results of the first and last comparisons. I have taken the conducting power in the first in all cases equal to 100 as compared with No. 19; in the last I have assumed that the conducting power of No. 15 has remained unaltered :—

	Conducting powers found, as compared with No. 19 = 100.				Conducting power found, as compared with No. 15 = 100.	
	1.		2.		3.	
	May 9, 1862.	T.	June 14, 1863.	T.		T.
1. Silver: hard-drawn	100·00	20·2	103·700	20·0	103·915	20·0
2. Silver: annealed	100·00	20·2	99·740	20·1	99·947	20·1
3. Silver: hard-drawn	100·00	20·2	102·590	20·2	102·807	20·2
4. Silver: annealed	100·00	20·2	99·825	20·0	100·031	20·0
5. Copper: hard-drawn	100·00	20·1	100·040	20·2	100·248	20·2
6. Copper: annealed...............	100·00	20·1	99·807	20·0	100·015	20·0
7. Copper: hard-drawn	100·00	20·0	99·941	19·8	100·149	19·8
8. Copper: annealed...............	100·00	20·0	95·358	20·4	95·556	20·4
9. Gold: hard-drawn	100·00	20·0	99·838	20·2	100·045	20·2
10. Gold: annealed	100·00	20·0	99·855	20·0	100·062	20·0
11. Gold: hard-drawn	100·00	20·0	99·662	20·2	99·869	20·2
12. Gold: annealed	100·00	20·0	99·670	20·3	99·877	20·3
13. Platinum: hard-drawn	100·00	20·0	99·744	20·2	99·951	20·2
14. Platinum: hard-drawn	100·00	20·0	99·792	20·2	99·999	20·2
15. Gold-silver alloy: hard-drawn	100·00	20·0	99·793	20·2	100·000	20·2
16. Gold-silver alloy: hard-drawn	100·00	19·9	99·756	20·3	99·963	20·3
17. German silver: annealed......	100·00	20·3	99·955	20·0	100·162	20·0
18. German silver: annealed......	100·00	20·3	99·938	20·0	100·145	20·0
19. German silver: annealed......	......	......	......	......	100·217	20·2

From the above it would appear that if the conducting power of No. 19 has remained constant, that of all the others has altered; but supposing such to be the case, it will be found on comparing the values that the conducting powers have all altered in a like extent. Is this probable? Is it not more probable that the conducting power of the German silver has changed, than that that of all the others should have altered in the same degree? If that of the gold-silver alloy, No. 15, be called 100·00 instead of 99·793, then, as will be seen from column 3, very few show any change in their conducting power. Those which show no sensible change are as follows :—

	Values taken from column 3.
No. 2. Silver: annealed..............	99·947
No. 4. Silver: annealed..............	100·031
No. 6. Copper: annealed	100·015
No. 9. Gold: hard-drawn	100·045
No. 10. Gold: annealed	100·062
No. 13. Platinum: hard-drawn	99·951
No. 14. Platinum: hard-drawn	99·999
No. 15. Gold-silver alloy: hard-drawn ..	100·000
No. 16. Gold-silver alloy: hard-drawn ..	99·963

The differences in the above are probably due to temperature; for as the wires are in tubes filled with carbonic-acid gas, we can never be absolutely sure that wire has exactly the same temperature as the bath. In properly made resistance-coils this source of error is materially diminished, and in some experiments which are about to be made to further test the electrical permanency of metals and alloys this source of error will be almost entirely obviated. It may be here again mentioned, that the reason of placing the wires in glass tubes filled with carbonic-acid gas was to obviate the oxidation of the metal or alloy by the oxygen of the air, or from the acids produced by the oxidation of the oil or fat with which the wires are covered when drawn, as the holes in the draw-plates are generally oiled or greased, &c.

Those whose conducting power has changed are as follows:—

	Values taken from column 3.
No. 1. Silver: hard-drawn	103·915
No. 3. Silver: hard-drawn	102·807
No. 5. Copper: hard-drawn	100·248
No. 7. Copper: hard-drawn	100·149
No. 8. Copper: annealed	95·556
No. 11. Gold: hard-drawn	99·869
No. 12. Gold: annealed	99·877
No. 17. German silver: annealed	100·162
No. 18. German silver: annealed	100·145
No. 19. German silver: annealed	100·217.

The cause of the change in the conducting powers of the alloys Nos. 1, 3, 5, 7 is undoubtedly due to their becoming somewhat annealed by age*. With No. 8 the alteration may be attributed to faulty soldering. That the conducting power of the German silver experimented with has altered is not a proof that all German silver will do so; for we find the gold wires Nos. 9 and 10 not altered, but Nos. 11 and 12 (which were cut from the same piece, but of a different one from the one from which Nos. 9 and 10 were taken) have altered. Further experiments are, however, required to prove whether the metals and alloys given above as constant in their conducting power are so or not.

Schröder van der Kolk states† that the conducting power of copper wire undergoes a change when even weak currents are allowed to pass through it. In order to see whether that of the above wires would suffer any change, the following experiment was arranged:—Nos. 1, 2, 5, 6, 9, 10, 13, 15, 17 were connected together, and a current from two Bunsen's cells was allowed to pass through them day and night for six days. The cells were cleaned every morning and evening, and the dilute sulphuric acid renewed. The experiment was carried out soon after, June 14, 1863. In the subjoined Table the conducting powers are given as found before and after the trial, compared with No. 19.

	Conducting power observed, as compared with No. 19=100.			
	Before.	T.	After.	T.
No. 1	103·700	20·0	103·775	20·2
No. 2	99·740	20·1	99·733	20·2
No. 5	100·040	20·2	100·045	20·2
No. 6	99·807	20·0	99·865	20·0
No. 9	99·838	20·2	99·860	20·2
No. 10	99·855	20·0	99·807	20·2

* Brit. Assoc. Report, 1862, p. 139.

† Pogg. Ann. 110, 452.

No. 13	99·744	20·2	99·766	20·2
No. 15	99·793	20·2	99·762	20·2
No. 17	99·955	20·0	99·926	20·2

From the above numbers it will be seen that the conducting power has not changed, the differences in the values being in all probability due, as above stated, to temperature.

If the passage of a current really altered the conducting power of a wire, then of what use would resistance-coils be? The above experiments prove that a much stronger current than is used for testing the resistance of a wire has no effect on it.

Appendix B.—*On the Variation of the Electric Resistance of Alloys due to Change of Temperature. By* A. Matthiessen, *F.R.S.*

In the Appendix to the Report of your Committee read at the Meeting held last year, I gave a Table containing the results of experiments with some alloys, made with a view to find out the alloy whose conducting power decreases with an increase of temperature in the smallest degree. With the same apparatus, &c., I have, in conjunction with Dr. C. Vogt, experimented with the following alloys.

(With each series the formula deduced from the observations for the correction of the conducting power for temperature is given, where λ is equal to the conducting power at the temperature $t°$ C. Silver (hard-drawn) is taken at $0°=100$.)

Composition of alloy by weight.

(1) Gold .... 95·3
Iron .... 4·7
Made from pure metals.
Hard-drawn.

Length 226 mm.; diameter 0·470 mm.

T.	Conducting power.
12·0	2·3573
56·0	2·3138
100·0	2·2798

$$\lambda=2·3708-0·0011555t+0·000002454t^2.$$

(2) Gold .... 95·0
Iron .... 5·0
Hard-drawn.

Length 284 mm.; diameter 1·217 mm.

T.	Conducting power.
15·0	2·0819
57·5	2·0424
100·0	2·0067

$$\lambda=2·0967-0·0010057t+0·000001052t^2.$$

This and the two following alloys were made by Messrs. Johnson and Matthey. No. 2 was made to check the results obtained with No. 1; for those given with Nos. 3 and 4 appeared to show that some mistake had been made with No. 1. That this was not the case is proved by No. 2. It is, however, a very curious fact that the percentage decrement increases in this manner, for in no other series of alloys has this behaviour been noticed. Its cause may be attributed to the existence of chemical combinations in the solid alloys of gold and iron.

Nos. 3 and 4 are very brittle, and therefore difficult to draw.

(3) Gold .... 90·0
Iron .... 10·0
Hard-drawn.

Length 184 mm.; diameter 0·943 mm.

T.	Conducting power.
14·0	1·9822
57·0	1·7951
100·0	1·7010

$$\lambda=2·0632-0·0061367t+0·00002513t^2.$$

		Length 145 mm.; diameter 0·758 mm.	
		T.	Conducting power.
(4) Gold	85·0	15·0	2·6239
Iron	15·0	57·5	2·2732
Hard-drawn.		100·0	1·9926

$$\lambda=2{\cdot}7645-0{\cdot}0096586t+0{\cdot}00001940t^2.$$

		Length 520 mm.; diameter 0·802 mm.	
		T.	Conducting power.
(5) Silver	75·0	11·0	8·4846
Palladium	25·0	55·5	8·3577
Made by Messrs. Johnson and Matthey.		100·0	8·2256
Hard-drawn.			

$$\lambda=8{\cdot}5152-0{\cdot}0027644t-0{\cdot}000001313t^2.$$

This alloy was formerly used by dentists on account of its elasticity. It was tested, as it appeared to answer some of the conditions required.

		Length 296·6 mm.; diameter 0·576 mm.	
		T.	Conducting power.
(6) Copper	63·3	15·72	21·807
Zinc..........	36·7	23·75	21·562
Made from pure metals.		39·28	21·116
Hard-drawn.		54·38	20·693
		69·31	20·300
		84·63	19·897
		99·43	19·327

$$\lambda=22{\cdot}274-0{\cdot}030601t+0{\cdot}00002980t^2.$$

		Length 190 mm.; diameter 0·381 mm.	
		T.	Conducting power.
(7) Copper	75·0	13·47	21·704
Zinc	25·0	24·07	21·413
Made from pure metals.		39·21	21·020
Hard-drawn.		53·65	20·647
		69·03	20·268
		83·71	19·915
		98·97	19·565

$$\lambda=22{\cdot}076-0{\cdot}028100t+0{\cdot}00002945t^2.$$

These alloys are given, as they approach in composition to that of brass. It seemed very desirable to test the influence of temperature on the alloy, as it was proposed by Jacobi as a unit of electric resistance.

		Length 322·5 mm.; diameter 0·524 mm.	
		T.	Conducting power.
(8) Copper	90·3	15·43	12·058
Tin	9·7	23·40	11·990
Made from pure metals.		40·35	11·852
Hard-drawn.		54·75	11·737
		69·78	11·619
		84·66	11·499
		98·70	11·391

$$\lambda=12{\cdot}186-0{\cdot}0084168t+0{\cdot}000003700t^2.$$

	Length 429 mm.; diameter 0·627 mm.	
(9) Copper .... 89·7	T.	Conducting power.
Tin .... 10·3	11·0	10·1386
Made from pure metals.	55·5	9·8710
Hard-drawn.	100·0	9·6526

$$\lambda=10{\cdot}212-0{\cdot}0068043t+0{\cdot}00001210t^2.$$

These alloys are given, as they approach in composition to that of ordinary gun-metal.

	Length 904·5 mm.; diameter 0·650 mm.	
(10) Gun-metal (Austrian).	T.	Conducting power.
Copper.	13·0	26·336
Zinc.	56·5	24·056
Iron.	100·0	22·121
A specimen obtained through the kindness of Mr. F. Abel.		
Hard-drawn.		

$$\lambda=27{\cdot}084-0{\cdot}058750t+0{\cdot}00009116t^2.$$

The conducting power of this alloy increased by heating to 100° for one day 5·7 per cent.—a larger increment than has been observed with any alloy. Generally, the conducting power of an alloy either remains constant or only varies 0·1 or 0·2 per cent. under the same conditions.

	Length 1564 mm.; diameter 0·525 mm.	
(11) Proof gold.	T.	Conducting power.
Hard-drawn.	15·0	68·969
	57·5	60·179
	100·0	53·387

$$\lambda=72{\cdot}548-0{\cdot}24692t+0{\cdot}0005531t^2.$$

	Length 2328 mm.; diameter 0·525 mm.	
(12) Standard silver.	T.	Conducting power.
Hard-drawn.	12·0	78·015
	56·0	69·301
	100·0	61·949

$$\lambda=80{\cdot}628-0{\cdot}22196t+0{\cdot}0003518t^2.$$

In the following Table I have given the results here obtained, with those of last year, in such a manner that they may be easily compared:—

	Conducting power at 0°.	Percentage decrement in conducting power between 0° & 100°
Pure iron*	16·81	39·2
Pure thallium*	9·16	31·4
Other pure metals in a solid state	....	29·3
Gold, with 15 p.c. iron	2·76	27·9
Proof gold	72·55	26·4
Standard silver	80·63	23·2
Gun-metal (Austrian)	27·08	18·3
Gold, with 10 p.c. iron	2·06	17·5
Gold, with 14·3 p.c. silver and 7·4 p.c. copper	44·47	15·5
Copper, with 36·7 p.c. zinc	22·27	12·4
Copper, with 25 p.c. zinc	22·08	11·5

* Proc. Roy. Soc. xii. 472, 1863.

Table (*continued*).

	Conducting power at 0°.	Percentage decrement in conducting power between 0°&100°
Silver, with 5 p.c. platinum*	31·64	11·3
Silver, with 9·8 p.c. platinum*	18·04	7·1
Copper, with 9·7 p.c. tin	12·19	6·6
The gold-silver alloy*	15·03	6·5
Platinum, with 33·4 p.c. iridium	4·54	5·9
Copper, with 10·3 p.c. tin	10·21	5·2
Gold, with 18·1 p.c. silver and 15·4 p.c. copper*	10·6	5·2
Gold, with 15·2 p.c. silver and 26·5 p.c. copper*	12·02	4·8
German silver*	7·80	4·4
Gold, with 5 p.c. iron	2·10	4·3
Gold, with 4·7 p.c. iron	2·37	3·8
Silver, with 25 p.c. palladium	8·52	3·4
Silver, with 33·4 p.c. platinum†	6·70	3·1

It will be observed that I have not yet been able to find an alloy whose conducting power decreases between 0° and 100° less than that of the alloy of silver with 33·4 p.c. platinum; and from results obtained in this direction in conjunction with Dr. Vogt, I am of opinion there will be great difficulty in doing so. We have already tested upwards of 100 alloys, and it is curious how few we have found whose conducting power varies less than that of German silver between 0° and 100°.

Appendix C.—*On the Elementary Relations between Electrical Measurements.* *By* Professor J. Clerk Maxwell *and* Mr. Fleeming Jenkin.

Part I.—Introductory.

1. *Objects of Treatise.*—The progress and extension of the electric telegraph has made a practical knowledge of electric and magnetic phenomena necessary to a large number of persons who are more or less occupied in the construction and working of the lines, and interesting to many others who are unwilling to be ignorant of the use of the network of wires which surrounds them. The discoveries of Volta and Galvani, of Oersted, and of Faraday are familiar in the mouths of all who talk of science, while the results of those discoveries are the foundation of branches of industry conducted by many who have perhaps never heard of those illustrious names. Between the student's mere knowledge of the history of discovery and the workman's practical familiarity with particular operations which can only be communicated to others by direct imitation, we are in want of a set of rules, or rather principles, by which the laws remembered in their abstract form can be applied to estimate the forces required to effect any given practical result.

We may be called on to construct electrical apparatus for a particular purpose. In order to know how many cells are required for the battery, and of what size they should be, we require to know the strength of current required, the electromotive force of the cells, and the resistance of the circuit. If we know the results of previous scientific inquiry, and are acquainted with the method of adapting them to the case before us, we may discover the proper arrangement at once. If we are unable to make any estimate of what is required before constructing the apparatus, we may have to encounter

* Proc. Roy. Soc. xii. 472, 1863. † Brit. Assoc. Report, 1862, p. 137.

numerous failures which might have been avoided if we had known how to make a proper use of existing data.

All exact knowledge is founded on the comparison of one quantity with another. In many experimental researches conducted by single individuals, the absolute values of those quantities are of no importance; but whenever many persons are to act together, it is necessary that they should have a common understanding of the measures to be employed. The object of the present treatise is to assist in attaining this common understanding as to electrical measurements.

2. *Derivation of Units from fundamental Standards.*—Every distinct kind of quantity requires a standard of its own, and these standards might be chosen quite independently of each other, and in many cases have been so chosen; but it is possible to deduce all standards of quantity from the fundamental standards adopted for length, time, and mass; and it is of great scientific and practical importance to deduce them from these standards in a systematic manner. Thus it is easy to understand what a square foot is when we know what a linear foot is, or to find the number of cubic feet in a room from its length, breadth, and height; because the foot, the square foot, and the cubic foot are parts of the same system of units. But the pint, gallon, &c., form another set of measures of volume which has been formed without reference to the system based on length; and in order to reduce the one set of numbers to the other, we have to multiply by a troublesome fraction, difficult to remember, and therefore a fruitful source of error.

The varieties of weights and measures which formerly prevailed in this country, when different measures were adopted for different kinds of goods, may be taken as an example of the principle of unsystematized standards, while the modern French system, in which everything is derived from the elementary standards, exhibits the simplicity of the systematic arrangement.

In the opinion of the most practical and the most scientific men, a system in which every unit is derived from the primary units with decimal subdivisions is the best whenever it can be introduced. It is easily learnt; it renders calculation of all kinds simpler; it is more readily accepted by the world at large; and it bears the stamp of the authority, not of this or that legislator or man of science, but of nature.

The phenomena by which electricity is known to us are of a mechanical kind, and therefore they must be measured by mechanical units or standards. Our task is to explain how these units may be derived from the elementary ones; in other words, we shall endeavour to show how all electric phenomena may be measured in terms of time, mass, and space only, referring briefly in each case to a practical method of effecting the observation.

3. *Standard Mechanical Units.*—In this country the standard of length is one yard, but a foot is the unit popularly adopted. In France it is the ten millionth part of the distance from the pole to the equator, measured along the earth's surface, according to the calculations of Delambre, and this measure is called a metre, and is equal to 3·280899 feet, or 39·37079 inches.

The standard unit of time in all civilized countries is deduced from the time of rotation of the earth about its axis. The sidereal day, or the true period of rotation of the earth, can be ascertained with great exactness by the ordinary observations of astronomers; and the mean solar day can be deduced from this by our knowledge of the length of the year. The unit of time adopted in all physical researches is one second of mean solar time.

The standard unit of mass is in this country the avoirdupois pound, as we received it from our ancestors. The grain is one 7000th of a pound. In the

French system it is the gramme derived from the unit of length, by the use of water at a standard temperature as a standard of density. One cubic centimetre of water is a gramme $=15{\cdot}43235$ grains $={\cdot}00220462$ lbs.

A table, showing the relative value of the standard and derived units in the British and metrical system, is given in § 55.

The unit of force adopted in this treatise is that force which will produce a unit of velocity in a free unit mass, by acting on it during a unit of time. This unit of force is equal to the weight of the unit mass divided by g, where g is the accelerating force of gravity

$$\left.\begin{array}{l} =32{\cdot}088\,(1+0{\cdot}005133\sin^2\lambda) \text{ in British units} \\ \text{or } =9{\cdot}78024\,(1+0{\cdot}005133\sin^2\lambda) \text{ in metrical units} \end{array}\right\} \text{at the level of the sea,}$$

λ being the latitude of the place of observation. A unit of force still very generally adopted is the weight of the standard mass. The value of the new unit is $\frac{1}{g}$ times the old or gravitation unit.

The unit of work adopted in this treatise is the unit of force, defined as above, acting through the unit of space (*vide* § 55).

4. *Dimensions of Derived Units.*—Every measurement of which we have to speak involves as factors measurements of time, space, and mass only; but these measurements enter sometimes at one power, and sometimes at another. In passing from one set of fundamental units to another, and for other purposes, it is useful to know at what power each of these fundamental measurements enters into the derived measure.

Thus the value of a force is directly proportional to a length and a mass, but inversely proportional to the square of a time. This is expressed by saying that the *dimensions* of a force are $\frac{LM}{T^2}$; in other words, if we wish to pass from the English to the French system of measurements, the French unit of force will be to the English as $\frac{3{\cdot}28\times15{\cdot}43}{1}:1$, or as $50{\cdot}6$ to 1; because there are $3{\cdot}28$ feet in a metre, and $15{\cdot}43$ grains in a gramme. If the minute were chosen as the unit of time, the unit of force would, in either system, be $\frac{1}{3600}$ of that founded on the second as unit.

A table of the dimensions of every unit adopted in the present treatise is given in § 55.

Part II.—The Measurement of Magnetic Phenomena.

5. *Magnets and Magnetic Poles.*—Certain natural bodies, as the iron ore called loadstone, the earth itself, and pieces of steel after being subjected to certain treatment, are found to possess the following properties, and are called magnets.

If one of these bodies be free to turn in any direction, the presence of another will cause it to set itself in a position which is conveniently described or defined by reference to certain imaginary lines occupying a fixed position in the two bodies, and called their magnetic axes. One object of our magnetic measurements will be to determine the force which one magnet exerts upon another. It is found by experiment that the greatest manifestation of force exerted by one long thin magnet on another occurs very near the ends of the two bars, and that the two ends of any one long thin magnet possess opposite qualities. This peculiarity has caused the name of "poles" to be given to

the ends of long magnets; and this conception of a magnet, as having two poles capable of exerting opposite forces joined by a bar exerting no force, is so much the most familiar that we shall not hesitate to employ it, especially as many of the properties of magnets may be correctly expressed in this way; but it must be borne in mind, in speaking of poles, that they do not really exist as points or centres of force at the ends of the bar, except in the case of long, infinitely thin, uniformly magnetized rods.

If we mark the poles of any two magnets which possess similar qualities, we find that the two marked poles repel each other, that two unmarked poles also repel each other; but that a marked and an unmarked pole attract each other. The pole which is repelled from the northern regions of the earth is called a positive pole; the other end the negative pole. The negative pole is generally marked N by British instrument-makers, and is sometimes called the north pole of the magnet, whereas it is obviously similar to the earth's south pole.

The strength of a pole is necessarily defined as proportional to the force it is capable of exerting on any other pole. Hence the force f exerted between two poles of the strengths m and m_1 must be proportional to the product $m\,m_1$. The force, f, is also found to be inversely proportional to the square of the distance, D, separating the poles, and to depend on no other quantity; hence we have, unless an absurd and useless coefficient be introduced,

$$f=\frac{m\,m_1}{D^2}. \qquad (1)$$

From which equation it follows that the unit pole will be that which at unit distance repels another similar pole with unit force; f will be an attraction or a repulsion according as the poles are of opposite or the same kinds. The dimensions of the unit magnetic pole are $\frac{L^{\frac{3}{2}}M^{\frac{1}{2}}}{T}$.

6. *Magnetic Field.*—It is clear that the presence of a magnet in some way modifies the surrounding space, since any other magnet brought into that space experiences a peculiar force. The neighbourhood of a magnet is, for convenience, called a magnetic field; and for the same reason the effect produced by a magnet is often spoken of as due to the magnetic field, instead of to the magnet itself. This mode of expression is the more proper, inasmuch as the same or a similar condition of space may be produced by the passage of electrical currents in the neighbourhood, without the presence of a magnet. Since the peculiarity of the magnetic field consists in the presence of a certain force, we may numerically express the properties of the field by measuring the strength and direction of the force, or, as it may be worded, the intensity of the field and the direction of the lines of force.

This direction at any point is the direction in which the force tends to move a free pole; and the intensity, H, of the field is necessarily defined as proportional to the force, f, with which it acts on a free pole; but this force, f, is also proportional to the strength, m, of the pole introduced into the field, and it depends on no other quantities; hence

$$f=m\mathrm{H}, \qquad (2)$$

and therefore the field of unit intensity will be that which acts with unit force on the unit pole.

The dimensions of H are $\frac{M^{\frac{1}{2}}}{L^{\frac{1}{2}}T}$.

The lines of force produced by a long thin bar-magnet near its poles will

radiate from the poles, and the intensity of the field will be equal to the quotient of the strength of the pole divided by the square of the distance from the pole; thus the unit field will be produced at the unit distance from the unit pole. In a uniform magnetic field the lines of force, as may be demonstrated, will be parallel; such a field can only be produced by special combinations of magnets, but a small field at a great distance from any one pole will be sensibly uniform. Thus, in any room unaffected by the neighbourhood of iron or magnets, the magnetic field due to the earth will be sensibly uniform; its direction will be that assumed by the dipping-needle.

7. *Magnetic Moment.*—In reality we can never have a single pole entirely free or disconnected from its opposite pole, and it is time to pass to the consideration of the effect produced on a material bar-magnet in a magnetic field. In a uniform field two equal opposite and parallel forces act on its poles, and tend to set it with the line joining those poles in the direction of the force of the field. When the magnet is so placed that the line joining the poles is at right angles to the lines of force in the field, this tendency to turn or "couple," G, is proportional to the intensity of the field, H, the strength of the poles, m, and the distance between them, l; or

$$G=mlH. \qquad (3)$$

ml, or the product of the strength of the poles into the length between them, is called the magnetic moment of the magnet; and from equation (3) it follows that, in a field of unit intensity, the couple actually experienced by any magnet in the above position measures its moment. The dimensions of the unit of magnetic moment are evidently $\frac{L^{\frac{5}{2}}M^{\frac{1}{2}}}{T}$.

8. *Intensity of Magnetization.*—The intensity of magnetization of a magnet may be measured by its magnetic moment divided by its volume.

The dimensions of the unit of magnetization are therefore $\frac{M^{\frac{1}{2}}}{L^{\frac{1}{2}}T}$, the same as in the case of intensity of field.

9. *Coefficient of Magnetic Induction.*—When certain bodies, such as soft iron, &c., are placed in the magnetic field, they become magnetized by "induction"; so that the intensity of magnetization is (except when great) nearly proportional to the intensity of the field.

In diamagnetic bodies, such as bismuth, the direction of magnetization is opposite to that of the field. In paramagnetic bodies, such as iron, nickel, &c., the direction of magnetization is the same as that of the field.

The coefficient of magnetic induction is the ratio of the intensity of magnetization to the intensity of the field, and is therefore a *numerical* quantity, positive for paramagnetic bodies, negative for diamagnetic bodies.

10. *Magnetic Potentials and Equipotential Surfaces.*—If we take a very long magnet, and, keeping one pole well out of the way, move the other pole from one point to another of the magnetic field, we shall find that the forces in the field do work on the pole, or that they act as a resistance to its motion, according as the motion is with or contrary to the force acting on the pole. If the pole moves at right angles to the force, no work is done.

The *magnetic potential* at any point in a magnetic field is measured by the work done by the magnetic forces on a unit pole during its motion from an infinite distance from the magnet producing the field to the point in question, supposing the unit pole to exercise no influence on the magnetic field in question. The idea of potential as a mathematical quantity having different

values at different points of space, was brought into form by Laplace*. The name of potential, and the application to a great number of electric and magnetic investigations, were introduced by George Green, in his Essay on Electricity (Nottingham, 1828).

An equipotential surface in a magnetic field is a surface so drawn, that the potential of all its points shall be equal. By drawing a series of equipotential surfaces corresponding to potentials 1, 2, 3 . . . . . . n, we may map out any magnetic field, so as to indicate its properties.

The magnetic force at any point is perpendicular to the equipotential surface at that point, and its intensity is the reciprocal of the distance between one surface and the next at that point. The dimensions of the unit of magnetic potential are $\frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T}$.

11. *Lines of Magnetic Force.*—There is another way of exploring the magnetic field, and indicating the direction and magnitude of the force at any point. The conception and application of this method in all its completeness is due to Faraday†. The full importance of this method cannot be recognized till we come to electromagnetic phenomena (§§ 22, 23, & 24).

A line, whose direction at any point always coincides with that of the force acting on the pole of a magnet at that point, is called a line of magnetic force. By drawing a sufficient number of such lines, we may indicate the *direction* of the force in every part of the magnetic field; but by drawing them according to rule, we may indicate the intensity of the force at any point as well as its direction. It has been shown ‡ that if, in any part of their course, the number of lines passing through unit of area is proportional to the intensity there, the same proportion between the number of lines in unit of area and the intensity will hold good in every part of the course of the lines.

All that we have to do, therefore, is to space out the lines in any part of their course, so that the number of lines which start from unit of area is *equal* to the number representing the intensity of the field there. The intensity at any other part of the field will then be measured by the number of lines which pass through unit of area there; each line indicates a constant and equal force.

12. *Relation between Lines of Force and Equipotential Surfaces.*—The lines of force are always perpendicular to the equipotential surfaces; and the number of lines passing through unit of area of an equipotential surface is the reciprocal of the distance between that equipotential surface and the next in order—a statement made above in slightly different language.

In a uniform field the lines of force are straight, parallel, and equidistant; and the equipotential surfaces are planes perpendicular to the lines of force, and equidistant from each other.

If one magnetic pole of strength m be alone in the field, its lines of force are straight lines, radiating from the pole equally in all directions; and their number is $4\pi m$. The equipotential surfaces are a series of spheres, whose centres are at the pole, and whose radii are m, $\frac{1}{2}m$, $\frac{1}{3}m$, $\frac{1}{4}m$, &c. In other magnetic arrangements these lines and surfaces are more complicated, but in all cases the calculation is simple; and in many cases the lines and surfaces can be graphically constructed without any calculation.

* Mécanique Céleste, liv. iii.

† Experimental Researches, vol. iii. art. 3122 *et passim.*

‡ *Vide* Maxwell on Faraday's Lines of Force, Cambridge Phil. Trans. 1857.

Part III.—Measurement of Electric Phenomena by their Electromagnetic Effects.

13. *Preliminary.*—Before treating of electrical measurements, the exact meaning in which the words "quantity," "current," "electromotive force," and "resistance" are used will be explained. But, in giving these explanations, we shall assume the reader to be acquainted with the meaning of such expressions as conductor, insulator, voltaic battery, &c.

14. *Meaning of the words "Electric Quantity."*—When two light conducting bodies are connected with the same pole of a voltaic battery, while the other pole is connected with the earth, they may be observed to repel one another. The two poles produce equal and similar effects. When the two bodies are connected with opposite poles, they attract one another. Bodies, when in a condition to exert this peculiar force one on the other, are said to be electrified, or charged with electricity. These words are mere names given to a peculiar condition of matter. If a piece of glass and a piece of resin are rubbed together, the glass will be found to be in the same condition as an insulated body connected with the copper pole of the battery, and the resin in the same condition as the body connected with the zinc pole of the battery. The former is said to be positively, and the latter negatively electrified. The propriety of this antithesis will soon appear. The force with which one electrified body acts on another, even at a constant distance, varies with different circumstances. When the force between the two bodies at a constant distance, and separated by air, is observed to increase, it is said to be due to an increase in the quantity of electricity; and the quantity at any spot is defined as proportional to the force with which it acts, through air, on some other constant quantity at a distance. If two bodies, charged each with a given quantity of electricity, are incorporated, the single body thus composed will be charged with the sum of the two quantities. It is this fact which justifies the use of the word "quantity."

Thus the quality in virtue of which a body exerts the peculiar force described is called electricity, and its quantity is measured (*cæteris paribus*) by measuring force.

The quantity thus defined produced on two similar balls similarly circumstanced, but connected with opposite poles of a voltaic battery, is equal, but opposite; so that the sum of these two equal and opposite quantities is zero; hence the conception of positive and negative quantities.

In speaking of a quantity of electricity, we need not conceive it as a separate thing, or entity distinct from ponderable matter, any more than in speaking of sound we conceive it as having a distinct existence. Still it is convenient to speak of the intensity or velocity of sound, to avoid tedious circumlocution; and quite similarly we may speak of electricity, without for a moment imagining that any real electric fluid exists.

The laws according to which the force described varies, as the shape of the conductors, their combinations, and their distances are varied, have been established by Coulomb, Poisson, Green, W. Thomson, and others. These will be found accurately described, independently of all hypothesis, in papers by Professor W. Thomson, published in the Cambridge Mathematical Journal, vol. i. p. 75 (1846), and a series of papers in 1848 and 1849.

15. *Meaning of the words "Electric Current."*—When two balls charged by the opposite poles of a battery, with opposite and equal quantities of electricity, are joined by a conductor, they lose in a very short time their peculiar properties, and assume a neutral condition intermediate between the

positive and negative states, exhibiting no electrical symptoms whatever, and hence described as unelectrified, or containing no electricity. But, during the first moment of their junction, the conductor is found to possess certain new and peculiar properties: any one part of the conductor exerts a force upon any other part of the conductor; it exerts a force on any magnet in the neighbourhood; and if any part of the conductor be formed by one of those compound bodies called electrolytes, a certain portion of this body will be decomposed. These peculiar effects are said to be due to a current of electricity in the conductor. The positive quantity, or excess, is conceived as flowing into the deficiency caused by the negative quantity; so that the whole combination is reduced to the neutral condition. This neutral condition is similar to that of the earth where the experiment is tried. If the balls are continually recharged by the battery, and discharged or neutralized by the wire, a rapid succession of the so-called currents will be sent; and it is found that the force with which a magnet is deflected by this rapid succession of currents is proportional (*cæteris paribus*) to the quantity of electricity passed through the conductor or neutralized per second; it is also found that the amount of chemical action, measured by the weights of the bodies decomposed, is proportional to the same quantity. The currents just described are intermittent; but a wire or conductor, used simply to join the two poles of a battery, acquires permanently the same properties as when used to discharge the balls as above with great rapidity; and the greater the rapidity with which the balls are discharged, the more perfect the similarity of the condition of the wire in the two cases. The wire in the latter case is therefore said to convey a permanent current of electricity, the magnitude or strength of which is defined as proportional to the quantity conveyed per second. This definition is expressed by the equation

$$C=\frac{Q}{t}, \quad \ldots \ldots \ldots \ldots \quad (4)$$

where C is the current, Q the quantity, and t the time. A permanent current flowing through a wire may be measured by the force which it exerts on a magnet; the actual quantity it conveys may be obtained by comparing this force with the force exerted under otherwise similar conditions, when a known quantity is sent through the same wire by discharges. The strength of a permanent current is found at any one time to be equal in all parts of the conductor. Conductors conveying currents exert a peculiar force one upon another; and during their increase or decrease they produce currents in neighbouring conductors. Similar effects are produced as they approach or recede from neighbouring conductors. The laws according to which currents act upon magnets and upon one another will be found in the writings of Ampère and Weber.

16. *Meaning of the words "Electromotive Force."*—Hitherto we have spoken simply of statical effects; but it is found that a current of electricity, as above defined, cannot exist without effecting work or its equivalent. Thus it either heats the conductor, or raises a weight, or magnetizes soft iron, or effects chemical decomposition; in fine, in some shape it effects work, and this work bears a definite relation to the current. Work done presupposes a force in action. The immediate force producing a current, or, in other words, causing the transfer of a certain quantity of electricity, is called an electromotive force. This force is necessarily assumed as ultimately due to that part of a circuit where a "degradation" or consumption of energy takes place: thus we speak of the electromotive force of the voltaic or thermo-

electric couple; but the term is also used independently of the source of power, to express the fact that, however caused, a certain force tending to do work by setting electricity in motion does, under certain circumstances, exist between two points of a conductor or between two separate bodies. But equal quantities of electricity transferred in a given time do not necessarily or usually produce equal amounts of work; and the electromotive force between two points, the proximate cause of the work, is defined as proportional to the amount of work done between those points when a given quantity of electricity is transferred from one point to another. Thus if, with equal currents in two distinct conductors, the work done in the one is double that done in the second in the same time, the electromotive force in the first case is said to be double that in the second; but if the work done in two circuits is found strictly proportional to the two currents, the electromotive force acting on the two currents is said to be the same. Defined in this way, the electromotive force of a voltaic battery is found to be constant so long as the materials of which it is formed remain in a similar or constant condition. The above definitions, in mathematical language, give $W = ECt$,

$$\text{or} \quad E = \frac{W}{Ct}, \quad \ldots\ldots\ldots\ldots \quad (5)$$

where E is the electromotive force, and W the work done. Thus the electromotive force producing a current in a conductor is equal to the ratio between the work done in the unit of time and the current effecting the work. This conception of the relations of work, electromotive force, current, and quantity will be aided by the following analogy:—A quantity of electricity may be compared to a quantity or given mass of water; currents of water in pipes in which equal quantities passed each spot in equal times would then correspond to equal currents of electricity; electromotive force would correspond to the head of water producing the current. Thus if, with two pipes conveying equal currents, the head forcing the water through the first was double that forcing it through the second, the work done by the water in flowing through the first pipe would necessarily be twice that done by the water in the second pipe; but if twice as much water passed through the first pipe as passed through the second, the work done by water in the first pipe would again be doubled. This corresponds exactly with the increase of work done by the electrical current when the electromotive force is doubled, and when the quantity is doubled.

Thus, to recapitulate, the quality of a battery or source of electricity, in virtue of which it tends to do work by the transfer of electricity from one point to another, is called its electromotive force, and this force is measured by measuring the work done during the transfer of a given quantity of electricity between those points. The relations between electromotive force and work were first fully explained in a paper by Professor W. Thomson on the application of the principle of mechanical effect to the measurement of electromotive forces published in the Philosophical Magazine for December 1851.

17. *Meaning of the words "Electric Resistance."*—It is found by experiment, that even when the electromotive force between two points remains constant, so that the work done by the transfer of a given quantity of electricity remains constant, nevertheless, by modifying the material and form of the conductor, this transfer may be made to take place in very different times; or, in other words, currents of very different magnitudes are produced, and very different amounts of work are done, in the unit of time. The quality of

the conductor in virtue of which it prevents the performance of more than a certain amount of work in a given time by a given electromotive force is called its electrical resistance. The resistance of a conductor is therefore inversely proportional to the work done in it when a given electromotive force is maintained between its two ends; and hence, by equation (5), it is inversely proportional to the currents which will then be produced in the respective conductors. But it is found by experiment that the current produced in any case in any one conductor is simply proportional to the electromotive force between its ends; hence the ratio $\frac{E}{C}$ will be a constant quantity, to which the resistance as above defined must be proportional, and may with convenience be made equal; thus

$$R=\frac{E}{C}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

an equation expressing Ohm's law. In order to carry on the parallel with the pipes of water, the resistance overcome by the water must be of such nature that twice the quantity of water will flow through any one pipe when twice the head is applied. This would not be the result of a constant mechanical resistance, but of a resistance which increased in direct proportion to the speed of the current; thus the electrical resistance must not be looked on as analogous to a simple mechanical resistance, but rather to a coefficient by which the speed of the current must be multiplied to obtain the whole mechanical resistance. Thus if the electrical resistance of a conductor be called R, the work, W, is not equal to CRt, but $C \times CR \times t$, or

$$W=C^2Rt\,*, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where C may be looked on as analogous to a quantity moving at a certain speed, and CR as analogous to the mechanical resistance which it meets with in its progress, and which increases in direct proportion to the quantity conveyed in the unit of time.

18. *Measurement of Electric Currents by their Action on a Magnetic Needle.*—In 1820, Oersted discovered the action of an electric current upon a magnet at a distance, and one method of measurement may be based on this action. Let us suppose the current to be in the circumference of a vertical circle, so that in the upper part it runs from left to right. Then a magnet suspended in the centre of the circle will turn with the end which points to the north away from the observer. This may be taken as the simplest case, as every part of the circuit is at the same distance from the magnet, and tends to turn it the same way. The force is proportional to the moment of the magnet, to the strength of the current as defined by § 15, to its length, and inversely to the square of its distance from the magnet.

Let the moment of the magnet be ml, the strength of the current C, the radius of the circle k, the number of times the current passes round the circle n, the angle between the axis of the magnet and the plane of the circle θ, and the moment tending to turn the magnet G, then

$$G=mlC \,.\, 2\pi nk\,\frac{1}{k^2}\cos\theta, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

which will be unity if ml, C, k, and the length of the circuit be unity, and if $\theta=0°$.

* By equation (5) we have $W=CEt$; but by equation (6) $R=\frac{E}{C}$; hence $W=C^2Rt$.—Q.E.D.

The unit of current founded on this relation, and called the electromagnetic unit, is therefore that current of which the unit of length placed along the circumference of a circle of unit radius produces a unit of magnetic force at the centre.

The usual way of measuring C, the strength of a current, is by making it describe a circle about a magnet, the plane of the circle being vertical and magnetic north and south. Thus, if H be the intensity of the horizontal component of terrestrial magnetism, and G the moment of this on the magnet, $G = mlH \sin\theta$, whence the strength of the current—

$$C = \frac{k^2}{2\pi n} H \tan\theta, \quad \ldots \ldots \ldots \quad (9)$$

where k is the radius of the circle, n the number of turns, H the intensity of the horizontal part of the earth's magnetic force as determined by the usual method, and θ the angle of deviation of the magnet suspended in the centre of the circle. As the strength of the current is proportional to the tangent of the angle θ, an instrument constructed on this plan is called a tangent galvanometer. The instrument called a sine galvanometer may also be used, provided the coil is circular. The equation is similar to that just given, substituting $\sin\theta$ for $\tan\theta$.

To find the dimensions of C, we must consider that what we observe is the force acting between a magnetic pole, m, and a current of given length, L, at a given distance, L_1, and that this force $= \frac{mCL}{L_1^2}$. Hence the dimensions of C, an electric current thus measured, are $\frac{L^{\frac{1}{2}} M^{\frac{1}{2}}}{T}$.

19. *Measurement of Electric Currents by their mutual action on one another.*—Hitherto we have spoken of the measurement of currents as dependent on their action upon magnets; but this measurement in the same units can as simply be founded on their mutual action upon one another. Ampère has investigated the laws of mechanical action between conductors carrying currents. He has shown that the action of a small closed circuit at a distance is the same as that of a small magnet, provided the axis of the magnet be placed normal to the plane of the circuit, and the moment of the magnet be equal to the product of the current into the area of the circuit which it traverses.

Thus, let two small circuits having areas A and A_1 be placed at a great distance D from each other in such a way that their planes are at right angles to each other, and that the line D is in the intersection of the planes. Now let currents C and C_1 circulate in these conductors; a force will act between them tending to make their planes parallel, and the direction of the currents opposite. The moment of this couple will be

$$G = \frac{AC \times A_1 C_1}{D^3}. \quad \ldots \ldots \ldots \ldots \quad (10)$$

Hence the unit electric current conducted round two circuits of unit area in vertical planes at right angles to each other, one circuit being at a great distance, D, vertically above the other, will cause a couple to act between the circuits of a magnitude $\frac{1}{D^3}$. The definition of the unit current (identical with the unit founded on the relations given in § 18) might be founded on this action quite independently of the idea of magnetism.

20. *Weber's Electro-Dynamometer.*—The measurement described in the last paragraph is only accurate when D is very great, and therefore the moment to be measured very small. Hence it is better to make the experimental measurements in another form. For this purpose, let a length (l) of wire be made into a circular coil of radius k; let a length (l_1) of wire be made into a coil of very much smaller radius, k_1. Let the second coil be hung in the centre of the first, the planes being vertical and at the angle θ. Then, if a current C traverses both coils, the moment of the force tending to bring them parallel will be

$$G = \tfrac{1}{2} C^2 \frac{l l_1 k_1}{k^2} \sin\theta. \quad \ldots\ldots\ldots\ldots \quad (11)$$

This force may be measured in mechanical units by the angle through which it turns the suspended coil, the forces called into play by the mechanical arrangements of suspension being known from the construction of the instrument. Weber used a bifilar suspension, by which the weight of the smaller coil was used to resist the moment produced by the action of the currents.

21. *Comparison of the Electro-magnetic and Electro-chemical action of Currents.*—Currents of electricity, when passed through certain compound substances, decompose them; and it is found that, with any given substance, the weight of the body decomposed in a given time is proportional to the strength of the current as already defined with reference to its electromagnetic effect. The voltameter is an apparatus of this kind, in which water is the substance decomposed. Special precautions have to be taken, in carrying this method of measurement into effect, to prevent variations in the resistance of the circuit, and consequently in the strength of the current. This subject is more fully treated in Part V. §§ 53, 54.

22. *Magnetic Field near a Current.*—Since a current exerts a force on the pole of a magnet in its neighbourhood, it may be said to produce a magnetic field (§ 6), and, by exploring this field with a magnet, we may draw lines of force and equipotential surfaces of the same nature as those already described for magnetic fields caused by the presence of magnets.

When the current is a straight line of indefinite length, like a telegraph-wire, a magnetic pole in its neighbourhood is urged by a force tending to turn it round the wire, so that this force is at any point perpendicular to the plane passing through this point and the axis of the current.

The equipotential surfaces are therefore a series of planes passing through the axis of the current, and inclined at equal angles to each other. The number of these planes is 4π C, where C is the strength of the current.

The lines of magnetic force are circles, having their centres in the axis of the current, and their planes perpendicular to it. The intensity of the magnetic force at a distance, k, from the current is the reciprocal of the distance between two equipotential surfaces, which shows the force to be $\frac{2C}{k}$.

The work done on a unit magnetic pole in going completely round the current is 4π C, whatever the path which the pole describes.

23. *Mechanical Action of a Magnetic Field on a closed Conductor conveying a Current.*—When there is mechanical action between a conductor carrying a current and a magnet, the force acting on the conductor must be equal and opposite to that acting on the magnet. Every part of the conductor is therefore acted on by a force perpendicular to the plane passing through its own direction and the lines of magnetic force due to the magnet, and equal to the

product of the length of the conductor, into the strength of the current, the intensity of the magnetic field, and the sine of the angle between the lines of force and the direction of the current. This may be more concisely expressed by saying, that if a conductor carrying a current is moved in a magnetic field, the work done on the conductor by the electromagnetic forces is equal to the product of the strength of the current into the *number* of lines of force which it cuts during its motion.

Hence we arrive at the following general law, for determining the mechanical action on a closed conductor carrying a current and placed in a magnetic field:—

Draw the lines of magnetic force. Count the number which pass through the circuit of the conductor, then any motion which increases this number will be aided by the electromagnetic forces, so that the work done during the motion will be the product of the strength of the current and the number of additional lines of force.

For instance, let the lines of force be due to a single magnetic pole of strength m. These are $4\pi m$ in number, and are in this case straight lines radiating equally in all directions from the pole. Describe a sphere about the pole, and project the circuit on its surface by lines drawn to the pole. The surface of the area so described on the sphere will measure the solid angle subtended by the circuit at the pole. Let this solid angle $=\omega$, then the number of lines passing through the closed surface will be $m\omega$; and if C be the strength of the current, the amount of work done by bringing the magnet and circuit from an infinite distance to their present position will be $Cm\omega$. This shows that the magnetic potential of a closed circuit carrying a unit current with respect to a unit magnetic pole placed at any point is equal to the solid angle which the circuit subtends at that point.

By considering at what points the circuit subtends equal solid angles, we may form an idea of the surfaces of equal potential. They form a series of sheets, all intersecting each other in the circuit itself, which forms the boundary of every sheet. The number of sheets is 4π C, where C is the strength of the current. The lines of magnetic force intersect these surfaces at right angles, and therefore form a system of rings, encircling every point of the circuit. When we have studied the general form of the lines of force, we can form some idea of the electromagnetic action of that current, after which the difficulties of numerical calculation arise entirely from the imperfection of our mathematical skill.

24. *General Law of the Mechanical Action between Electric Currents and other Electric Currents or Magnets.*—Draw the lines of magnetic force due to all the currents, magnets, &c., in the field, supposing the strength of each current or magnet to be reduced from its actual value to unity. Call the number of lines of force due to a circuit or magnet, which pass through another circuit, the potential coefficient between the one and the other. This number is to be reckoned positive when the lines of force pass through the circuit in the same direction as those due to a current in that circuit, and negative when they pass in the opposite direction.

If we now ascertain the change of the potential coefficient due to any displacement, this increment multiplied by the product of the strengths of the currents or magnets will be the amount of work done by the mutual action of these two bodies during the displacement. The determination of the actual value of the potential coefficient of two things, in various cases, is an important part of mathematics as applied to electricity. (See the mathematical discussion of the experiments, Appendix D.)

25. *Electromagnetic Measurement of Electric Quantity.*—A conducting body insulated at all points from the neighbouring conductors may in various ways be electrified, or made to hold a quantity of electricity. This quantity (§ 14) is perfectly definite in any given circumstances; it cannot be augmented or diminished so long as the conductor is insulated, and is called the charge of the conductor. Its magnitude depends on the dimensions and shape and position of the insulated and the neighbouring conductors, on the insulating material, and finally on the electromotive force between the insulated and the neighbouring conductors, at the moment when the charge was produced. The well-known Leyden jar is an arrangement by which a considerable charge can be obtained on a small conductor with moderate electromotive force between the inner and outer coatings which constitute respectively the "insulated" and "neighbouring" conductors referred to in general. We need not enter into the general laws determining the charge, since our object is only to show how it may be measured when already existing; but it may be well to state that the quantity on the charged insulated conductor necessarily implies an equal and opposite quantity on the surrounding or neighbouring conductors.

We have already defined the magnitude of a current of electricity as simply proportional to the quantity of electricity conveyed in a given time, and we have shown a method of measuring currents consonant with this definition. The unit quantity will, therefore, be that conveyed by the unit current as above defined in the unit of time. Thus, if a unit current is allowed to flow for a unit of time in any wire connecting the two coatings of a Leyden phial, the quantity which one coating loses, or which the other gains, is the electromagnetic unit quantity*. The measurement thus defined of the quantity in a given statical charge can be made by observing the swing of a galvanometer-needle produced by allowing the charge to pass through the coil of the galvanometer in a time extremely short compared with that occupied by an oscillation of the needle.

Let Q be the whole quantity of electricity in an instantaneous current, then

$$Q = 2\frac{C_1 t}{\pi}\sin\tfrac{1}{2}i, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where C_1 = the strength of a current giving a unit deflection (45° on a tangent or 90° on a sine galvanometer), t = half the period or time of a complete oscillation of the needle of the galvanometer under the influence of terrestrial magnetism alone, and i = the angle to which the needle is observed to swing from a position of rest, when the discharge takes place; C_1 is a constant which need only be determined once for each instrument, provided the horizontal force of the earth's magnetism remain unchanged. In the case of the tangent galvanometer, the formula for obtaining it has already been given. From equations (9) and (12) we have for a tangent galvanometer

$$Q = \frac{k}{\pi^2 n} Ht\sin\tfrac{1}{2}i, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

where, as before, k = the radius of the coil, and n = the number of turns made by the wire round the coil.

The quantity in a given charge which can be continually reproduced under fixed conditions may be measured by allowing a succession of discharges to pass at regular and very short intervals through a galvanometer, so as to pro-

* Weber calls this quantity two units—a fact which must not be lost sight of in comparing his results with those of the Committee.

duce a permanent deflection. The value of a current producing this deflection can be ascertained, and the quotient of this value by the number of discharges taking place in the "second," gives the value of each charge in electromagnetic measure.

To find the dimensions of Q, we simply observe that the unit of electricity is that which is transferred by the unit current in the unit of time. Multiplying the dimensions of C by T, we find the dimensions of Q are $L^{\frac{1}{2}} M^{\frac{1}{2}}$.

26. *Electric Capacity of a Conductor.*—It is found by experiment that, other circumstances remaining the same, the charge on an insulated conductor is simply proportional to the electromotive force between it and the surrounding conductors, or, in other words, to the difference of potentials (47). The charge that would be produced by the unit electromotive force is said to measure the electric capacity of a conductor. Thus, generally, the capacity of a conductor $S=\frac{Q}{E}$, where Q is the whole quantity in the charge produced by the electromotive force, E. When the electromotive force producing the charge is capable of maintaining a current, the capacity of the conductor may be obtained without a knowledge of the value either of Q or E, provided we have the means of measuring the resistance of a circuit in electromagnetic measure. For let R be the resistance of a circuit, in which the given electromotive force, E, will produce the unit deflection on a tangent galvanometer, then, from equations (6) and (12), we have

$$S=2\frac{t\sin\frac{1}{2}i}{\pi R_1}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

where t and i retain the same signification as in equation (13) (§ 25).

27. *Direct Measurement of Electromotive Force.*—The meaning of the words "electromotive force" has already been explained (§ 16); this force tends to do work by means of a current or transfer of electricity, and may therefore be said to produce and maintain the current. In any given combination in which electric currents flow, the immediate source of the power by which the work is done is said to produce the electromotive force. The sources of power producing electromotive force are various. Of these, chemical action in the voltaic battery, unequal distribution of temperature in circuits of different conductors, the friction of different substances, magnetoelectric induction, and simple electric induction are the most familiar. An electromotive force may exist between two points of a conductor, or between two points of an insulator, or between an insulator and a conductor,—in fine, between any points whatever. This electromotive force may be capable of maintaining a current for a long time, as in a voltaic battery, or may instantly cease after producing a current of no sensible duration, as when two points of the atmosphere at different potentials (§ 47) are joined by a conductor; but in every case in which a constant electromotive force, E, is maintained between any two points, however situated, the work spent or gained in transferring a quantity, Q, of electricity from one of those points to the other will be constant; nor will this work be affected by the manner or method of the transfer. If the electricity be slowly conveyed as a static charge on an insulated ball, the work will be spent or gained in accelerating or retarding the ball; if the electricity be conveyed rapidly through a conductor of small resistance, or more slowly through a conductor of great resistance, the work may be spent in heating the conductor, or it may electrolyze a solution, or be thermoelectrially or mechanically used; but in all cases the change effected, measured as equiva-

lent to work done, will be the same, and equal to EQ. Hence the electromotive force between two points is unity, if a unit of mechanical work is spent (or gained) in the transfer of a unit of electricity from one point to the other. This general definition is due to Professor W. Thomson.

The direct measurement of electromotive force would be given by the measure, in any given case, of the work done by the transfer of a given quantity of electricity. The ratio between the numbers measuring the work done, and the quantity transferred, would measure the electromotive force. This measurement has been made by Dr. Joule and Professor Thomson, by determining the heat developed in a wire by a given current measured as in (§ 18)*.

28. *Indirect Measurements of Electromotive Force.*—The direct method of measurement is in most cases inconvenient, and in many impossible; but the indirect methods are numerous and easily applied. The relation between the current, C, the resistance, R, and the electromotive force, E, expressed by Ohm's law (equation 6), will determine the electromotive force of a battery whenever R and C are known. A second indirect method depends on the measurement of the statical force with which two bodies attract one another when the given electromotive force is maintained between them. This method is fully treated in Part IV. (43). The phenomenon on which it is based admits of an easy comparison between various electromotive forces by electrometers. This method is applicable even to those cases in which the electromotive force to be measured is incapable of maintaining a current. The laws of chemical electrolysis and electromagnetic induction afford two other indirect methods of estimating electromotive force in special cases (54 and 31).

29. *Measurement of Electric Resistance.*—We have already stated that the resistance of a conductor is that property in virtue of which it limits the amount of work performed by a given electromotive force in a given time, and we have shown that it may be measured by the ratio $\frac{E}{C}$ of the electromotive force between two ends of a conductor to the current maintained by it. The unit resistance is, therefore, that in which the unit electromotive force produces the unit current, and therefore performs the unit of work in the unit of time. If in any circuit we can measure the current and electromotive force, or even the ratio of these magnitudes, we should, *ipso facto*, have measured the resistance of the circuit. The methods by which this ratio has been measured, founded on the laws of electromagnetic induction, are fully described in Appendix D. Other methods may be founded on the measurement of currents and electromotive forces, described in 18, 19, 20, 27, and 28. Lastly, a method founded on the gradual loss of charge through very great resistances will be found in Part IV. (45). The equation (25) there given for electrostatic measure is applicable to electromagnetic measure when the capacity and difference of potentials are expressed in electromagnetic units.

30. *Electric Resistance in Electromagnetic Units is measured by an Absolute Velocity.*—The dimensions of R are found, by comparing those of E and C, to be $\frac{L}{T}$, or those of a simple velocity. This velocity, as was pointed out by Weber, is an absolute velocity in nature, quite independent of the magnitude of the fundamental units in which it is expressed. The following illustration, due to Professor Thomson, will show how a velocity may express a resistance, and also how that expression may be independent of the magnitude of the units of time and space.

* Phil. Mag. vol. ii. 4th Ser. 1851, p. 551.

Let a wire of any material be bent into an arc of $57\frac{1}{4}°$ with any radius, k. Let this arc be placed in the magnetic meridian of any magnetic field, with a magnet of any strength freely suspended in the centre of the arc. Let two vertical wires or rails, separated by a distance equal to k, be attached to the ends of the arc; and let a cross piece slide along these rails, inducing a current in the arc. Then it may be shown that the speed required to produce a deflection of 45° on the magnet will measure the resistance of the circuit, which is assumed to be constant. This speed will be the same whatever be the value of k, or the intensity of the magnetic field, or the moment of the magnet. In this form the experiment could not be easily carried out; but if a length, l, of wire be taken and rolled into a circular coil at the radius k, and the distance between the vertical rails be taken equal to $\frac{k^2}{l}$, then if the resistance of the circuit be the same as in the previous case, the deflection of 45° will be produced by the same velocity in the cross piece, measuring that resistance; or, generally, if the distance between the rails be $p\,\frac{k^2}{l}$, then p times the velocity required to produce the unit deflection (45°) will measure the resistance. The truth of this proposition can easily be established when the laws of magneto-electric induction have been understood (31).

31. *Magneto-electric Induction.*—Let a conducting circuit be placed in a magnetic field. Let C be the intensity of any current in that circuit; E the magnitude of the electromotive force acting in the circuit. Let the circuit be so moved that the number of lines of magnetic force (11) passing through it is increased by N in the time t, then (23) the electromagnetic forces will contribute towards the motion an amount of work measured by CN. Now Q, the quantity of electricity which passes, is equal to Ct; so that the work done on the current is EQ or CEt. By the principle of conservation of energy, the work done by the electromagnetic forces must be at the expense of that done by the electromotive forces, or

$$CN+CEt=0;$$

or dividing by Ct, we find that

$$E=-\frac{N}{t}; \qquad (15)$$

or, in other words, if the number of lines of force passing through a circuit be increased, an electromotive force in the negative direction will act in the circuit measured by the number of lines of force added per second.

If R be the resistance of the circuit, we have by Ohm's law (equation 6) $E=CR$; and therefore

$$N=-Et=-RCt=-RQ; \qquad (16)$$

or, in other words, if the number of lines of magnetic force passing through the circuit is altered, a current will be produced in the circuit in the direction opposite to that of a current which would have produced lines of force in the direction of those added, and the quantity of electricity which passes multiplied by the resistance of the circuit measures the number of additional lines passing through the circuit.

The facts of magneto-electric induction were discovered by Faraday, and described by him in the First Series of his "Experimental Researches in Electricity," read to the Royal Society, 24th November, 1831.

He has shown* the relation between the induced current and the lines of

* Experimental Researches, 3082, &c.

force cut by the circuit, and he has also described the state of a conductor in a field of force as a state the change of which is a cause of currents. He calls it the electrotonic state, and, as we have just seen, the electrotonic state may be *measured* by the number of lines of force which pass through the circuit at any time.

The measure of electromotive force used by W. Weber, and derived by him (independently of the principle of conservation of energy) from the motion of a conductor in a magnetic field, is the same as that at which we have arrived; for, from equation (15), we find that the unit electromotive force will be produced by motion in a magnetic field when one line of force is added (or subtracted) per unit of time, and this will occur when in a field of unit intensity a straight bar of unit length, forming part of a circuit otherwise at rest, is moved with unit velocity perpendicularly to the lines of force and to its own direction.

To W. Weber, whose numerical determinations of electrical magnitudes are the starting-point of exact science in electricity, we owe this, the first definition of the unit of electromotive force; but to Professor Helmholtz* and to Professor W. Thomson†, working independently of each other, we owe the proof of the necessary existence of magneto-electric induction and the determination of electromotive force on strictly mechanical principles.

32. *On Material Standards for the Measurement of Electrical Magnitudes.*—The comparison between two different electrical magnitudes of the same nature, *e. g.* between two currents or between two resistances, is in all cases much simpler than the direct measurements of these magnitudes in terms of time, mass, and space, as described in the foregoing pages. Much labour is, therefore, saved by the use of standards of each magnitude; and the construction and diffusion of those standards form part of the duties of the Committee.

Electric currents are most simply compared by "electro-dynamometers" (20)—instruments which, unlike galvanometers, are practically independent of the intensity of the earth's magnetism. When an instrument of this kind has been constructed, with which the values of the currents corresponding to each deflection have been measured (19, 20), other instruments may easily be so compared with this standard, that the relative value of the deflections produced by equal currents on the standard and the copies shall be known. Hence the absolute value of the current indicated by each deflection of each copy will be known in absolute measure. In other words, in order to obtain the electromagnetic measure of a current in the system described, each observer in possession of an electro-dynamometer which has been compared with the standard instrument will simply multiply by a constant number the deflection produced by the current on his instrument (or the tangent or sine of the deflection, according to the particular construction of the instrument).

Electric quantities may be compared by the swing of the needle of a galvanometer of any kind. They may be measured by any one in possession of a standard electro-dynamometer, or resistance-coil, since the observer will then be in a position directly to determine C_1 in equation (12), or R_1 in equation (14).

Capacities may be compared by the methods described (26); and a Leyden jar or condenser (41) of unit capacity, and copies derived from it, may be prepared and distributed. The owner of such a condenser, if he can measure electromotive force, can determine the quantity in his condenser.

* Paper read before the Physical Society of Berlin, 1847 (*vide* Taylor's Scientific Memoirs, part ii. Feb. 1853, p. 114).

† Transactions of the British Association, 1848; Phil. Mag. Dec. 1851.

The material standard for *electromotive force* derived from electromagnetic phenomena would naturally be a conductor of known shape and dimensions, moving in a known manner in a known magnetic field. Such a standard as this would be far too complex to be practically useful: fortunately a very simple and practical standard or gauge of electromotive force can be based on its statical effects, and will be described in treating of those effects (Part IV. 43). A practical standard for approximate measurements might be formed by a voltaic couple, the constituent parts of which were in a standard condition. It is probable that the Daniell's cell may form a practical standard of reference in this way, when its value in electromagnetic measure is known. This value lies between 9×10^7 and 11×10^7.

Resistances are compared by comparing currents produced in the several conductors by one and the same electromotive force. The unit resistance, determined as in Appendix D, will be represented by a material conductor; simple coils of insulated wire compared with this standard, and issued by the Committee, will allow any observer to measure any resistance in electromagnetic measure.

Part IV.—Measurement of Electric Phenomena by Statical Effects.

33. *Electrostatic Measure of Electric Quantity.*—By the application of a sufficient electromotive force between two parts of a conductor which does not form a circuit, it is possible to communicate to either part a *charge* of electricity which may be maintained in both parts, if properly insulated (14). With the ordinary electromotive forces due to induction or chemical action, and the ordinary size of insulated conductors, the charge of electricity in electromagnetic measure is exceedingly small; but when the capacity of the conductor is great, as in the case of long submarine cables, the charge may be considerable. By making use of the electromotive force produced by the friction of unlike substances, the charge or electrification even of small bodies may be made to produce visible effects. The electricity in a charge is not essentially in motion, as is the case with the electricity in a current. In other words, a charge may be permanently maintained without the performance of work. Electricity in this condition is therefore frequently spoken of as statical electricity, and its effects, to distinguish them from those produced by currents, may be called statical effects. The peculiar properties of electrically charged bodies are these:—

1. When one body is charged positively (14), some other body or bodies must be charged negatively to the same extent.

2. Two bodies repel one another when both are charged positively, or both negatively, and attract when oppositely charged.

3. These forces are inversely proportional to the square of the distance of the attracting or repelling charges of electricity.

4. If a body electrified in any given invariable manner be placed in the neighbourhood of any number of electrified bodies, it will experience a force which is the resultant of the forces that would be separately exerted upon it by the different bodies if they were placed in succession in the positions which they actually occupy, without any alteration in their electrical conditions.

From these propositions it follows that, at a given distance, the force, f, with which two small electrified bodies repel one another is proportional to the product of the charges, q and q_1, upon them. But when the distance

varies, this force, f, is inversely proportional to the square of the distance, d, between them; hence

$$f=\frac{qq_1}{d^2}. \qquad \qquad (17)$$

When q and q_1 are of dissimilar signs, f becomes negative, *i.e.* there is an attraction, and not a repulsion. This equation is incompatible with the electromagnetic definitions given in Part III., and, if it be allowed to be fundamental, gives a new definition of the unit quantity of electricity, as that quantity which, if placed at unit distance from another equal quantity of the same kind, repels it with unit force.

34. *Electrostatic System of Units.*—This new measurement of quantity forms the foundation of a distinct system or series of units, which may be called the electrostatic units, and measurements in these units will in these pages be designated by the use of small letters; thus, as Q, C, &c., signified quantity, current, &c., in *electromagnetic* measure, so q, c, e, and r, &c., will represent the *electrostatic* measure of quantity, current, electromotive force, resistance, &c.

The relations between current and quantity, between work, current, and electromotive force, and between electromotive force, current, and resistance, remain unchanged by the change from the electromagnetic to the electrostatic system.

35. *Ratio between Electrostatic and Electromagnetic Measures of Quantity.*—Since the expression forming the second member of equation (17) represents a force the dimensions of which are $\frac{\text{LM}}{\text{T}^2}$, the dimensions of q are $\frac{\text{L}^{\frac{3}{2}}\text{M}^{\frac{1}{2}}}{\text{T}}$. The dimensions of the unit of electricity, Q, in the electromagnetic system are $\text{L}^{\frac{1}{2}}\text{M}^{\frac{1}{2}}$ (25). Hence, since in passing from the one system to the other we must employ the ratio $\frac{q}{\text{Q}}$, this ratio will be of the dimensions $\frac{\text{L}}{\text{T}}$; that is to say, the ratio $\frac{q}{\text{Q}}$ is a velocity. In the present treatise this velocity will be designated by the letter v.

The first estimate of the relation between quantity of electricity measured statically and the quantity transferred by a current in a given time was made by Faraday*. A careful experimental investigation by MM. Weber and Kohlrausch† not only confirms the conclusion that the two kinds of measurement are consistent, but shows that the velocity $v=\frac{q}{\text{Q}}$ is 310,740,000 metres per second—a velocity not differing from the estimated velocity of light more than the different determinations of the latter quantity differ from each other. v must always be a constant, real velocity in nature, and should be measured in terms of the system of fundamental units adopted in electrical measurements (3 and 55). A redetermination of v (46) will form part of the present Committee's business in 1863–64. It will be seen that, by definition, the quantity transmitted by an electromagnetic unit current in the unit time is equal to v electrostatic units of quantity.

36. *Electrostatic Measure of Currents.*—In any coherent system, a current

* Experimental Researches, series iii. § 361, &c.

† Abhandlungen der König. Sächsischen Ges. Bd. iii. (1857) p. 260; or, Poggendorff's Annalen, Bd. 99. p. 10 (Aug. 1856).

is measured by the quantity of electricity which passes in the unit of time (15); if both current and quantity are measured in electrostatic units, then

$$c=\frac{q}{t}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

The dimensions of c are therefore $\frac{L^{\frac{3}{2}}M^{\frac{1}{2}}}{T^2}$; and in order to reduce a current from electromagnetic to electrostatic measure, we must multiply C by v, or

$$c=vC. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

37. *Electrostatic Measure of Electromotive Force.*—The statical measure of an electromotive force is the work which would be done by electrical forces during the passage of a unit of electricity from one point to another. The only difference between this definition and the electromagnetic definition (16 and 27) consists in the change of the unit of electricity from the electromagnetic to the electrostatic.

Hence if q units of electricity are transferred from one place to another, the electromotive force between those places being e, the work done during the transfer will be qe; but we found (27) that if E and Q be the electromagnetic measures of the same quantities, the work done would be expressed by QE; hence

$$qe=QE;$$

but (35)
$$q=vQ,$$

therefore
$$e=\frac{E}{v}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (20)$$

Thus, to reduce electromotive force from electromagnetic to electrostatic measure, we must divide by v.

The dimensions of e are $\frac{L^{\frac{1}{2}}M^{\frac{1}{2}}}{T}$.

38. *Electrostatic Measure of Resistance.*—If an electromotive force, e, act on a conductor whose resistance in electrostatic measure is r, and produce a current, c, then by Ohm's law

$$r=\frac{e}{c}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (21)$$

Substituting for e and c their equivalents in electromagnetic measure (equations 19 and 20), we have

$$r=\frac{1}{v^2}\frac{E}{C};$$

but (eq. 7)
$$R=\frac{E}{C},$$

and therefore
$$r=\frac{1}{v^2}R. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

To reduce a resistance measured in electromagnetic units to its electrostatic value, we must divide by v^2.

The dimensions of r are $\frac{T}{L}$, or the reciprocal of a velocity.

39. *Electric Resistance in Electrostatic Units is measured by the Reciprocal of an Absolute Velocity.*—We have seen from the last paragraph that the

dimensions of r establish this proposition; but the following independent definition, due to Professor W. Thomson, assists the mind in receiving this conception as a necessary natural truth. Conceive a sphere of radius k, charged with a given quantity of electricity, Q. The potential of the sphere, when at a distance from all other bodies, will be $\frac{Q}{k}$ (40, 41, and 47). Let it now be discharged through a certain resistance, r. Then if the sphere could collapse with such a velocity that its potential should remain constant, or, in other words, that the ratio of the quantity on the sphere to its radius should remain constant, during the discharge, then the time occupied by its radius in shrinking the unit of length would measure the resistance of the discharging conductor in electrostatic measure, or the velocity with which its radius diminished would measure the conducting power (50) of the discharging conductor. Thus the conducting power of a few yards of silk in dry weather might be an inch per second, in damp weather a yard per second. The resistance of 1000 miles of pure copper wire, $\frac{1}{16}$ inch in diameter, would be about 0·00000141 of a second per metre, or its conducting power one metre per 0·00000141 of a second, or 708980 metres per second.

40. *Electrostatic Measure of the Capacity of a Conductor.*—The electrostatic capacity of a conductor is equal to the quantity of electricity with which it can be charged by the unit electromotive force. This definition is identical with that given of capacity measured in electromagnetic units (26). Let s be the capacity of a conductor, q the electricity in it, and e the electromotive force charging it; then

$$q=se. \qquad (23)$$

From this equation we can see that the dimension of the quantity s is a length only. It will also be seen that

$$s=v^2S, \qquad (24)$$

where S is the electromagnetic measure of the capacity of the conductor with the electrostatic capacity, s.

The capacity of a spherical conductor in an open space is, in electrostatic measure, equal to the radius of the sphere—a fact demonstrable from the fundamental equation (17).

Experimentally to determine s, the capacity of the conductor in electrostatic measure, charge it with a quantity, q, of electricity, and measure in any unit its potential (47) or tension (49), e. Then bring it into electrical connexion with another conductor whose capacity, s_1, is known. Measure the potential, e_1, of s and s_1 after the charge is divided between them; then

$$q=se=(s+s_1)e_1,$$

and hence

$$s=\frac{e_1}{e-e_1}s_1 \qquad (25)$$

In this measurement we do not require to know e and e_1 in absolute measure, since the ratio of these two quantities only is required. We must, however, know the value of s_1, and hence we must begin either with a spherical conductor in a large open space, whose capacity is measured by its radius, or with some other form of absolute condenser alluded to in the following paragraph.

41. *Absolute Condenser. Practical Measurement of Quantity.*—As soon as the electromotive force of a source of electricity is known in electrostatic measure, the quantity which it will produce in the form of charge on simple forms is known by the laws of electrical distribution experimentally proved

by Coulomb. Simple forms of this kind may be termed *absolute condensers.* A sphere in an open space is such a condenser, and the quantity it contains is se (eq. 23). A more convenient form is a sphere of radius x, suspended in the centre of a hollow sphere, radius y, the latter being in communication with the earth. The capacity, s, of the internal sphere is then, by calculation,

$$s=\frac{xy}{y-x}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (26)$$

By a series of condensers of increasing capacity, we may measure the capacity of any condenser, however large. The comparison is made by the method described above (40). Thus, the practical method of measuring quantity in electrostatic measure is first to determine the capacity of the conductor containing the charge, and then to multiply that capacity by the electromotive force producing the charge (43).

42. *Practical Measurement of Currents.*—The electrostatic value of currents can be obtained from equation (21), when e and r are known, or from equation (19), when v and C are known, or by comparison with a succession of discharges of known quantities from an absolute condenser.

43. *Practical Measurement of Electromotive Force.*—The relations expressed by eq. (17) and (23) show that in any given circumstances the force exerted between two bodies due to the effects of statical electricity will be proportional to the electromotive force or difference of potential (47) between them. This fact allows us to construct gauges of electromotive force, or instruments so arranged that a given electromotive force between two parts of the apparatus brings an index into a sighted position. In order that the gauge should serve to *measure* the electromotive force absolutely, it is necessary that two things should be known: first, the distribution of the electricity over the two attracting or repelling masses (or, in other words, the capacity of each part); secondly, the absolute force exerted between them. For simple forms, the distribution, or capacity of each part can be calculated from the fundamental principles (33); the force actually exerted can be weighed by a balance. By these means Professor W. Thomson* determined the electromotive force of a Daniell's cell to be 0·0021 in British electrostatic units, or 0·0002951 in metrical units. This proposition is equivalent to saying that two balls of a metre radius, at a distance d apart in a large open space, and in connexion with the opposite poles of a Daniell's cell, would attract one another with a force equal to $\frac{0 \cdot 0002951}{d^2}$ absolute units, or $\frac{0 \cdot 0000239}{d^2}$ gramme weight.

An apparatus by which such a measurement as the foregoing can be carried out is called an absolute electrometer. It will be observed that, although the definition of electromotive force is founded on the idea of work, its practical measurement is effected by observing a force, inasmuch as when this force exerted between two conductors of simple shape is known, the work which the passage of a unit of electricity between them would perform may be calculated by known laws.

44. *Comparison of Electromotive Forces by their Statical Effects.*—This comparison is simpler than the absolute measurement, inasmuch as it is not necessary, in comparing two forces, to know the absolute values of either. Instruments by which the comparison can be made are called electrometers. Their arrangement is of necessity such that the force exerted between two given parts of the instrument shall be proportional to the difference of potential

* Paper read before the Royal Society, February 1860. *Vide* Proceedings of the Royal Society, vol. x. p. 318, and Phil. Mag. vol. xx. 4th Ser. 1860, p. 233.

between them. This force may be variable and measured by the torsion of a wire, as in Thomson's reflecting electrometer, or it may be constant, and the electromotive forces producing it may be compared by measuring the distance required in each case between the two electrified bodies to produce that constant force. The latter arrangement is adopted in Professor Thomson's portable electrometer, first exhibited at the present meeting of the Association. The indications of a gauge or electrometer not in itself absolute may be reduced to absolute measurement by multiplication into a constant coefficient.

45. *Practical Measurement of Electric Resistance.*—The electrostatic resistance of a conductor of great resistance (such as gutta percha or india rubber) might be directly obtained in the following manner:—Let a body of known capacity, s (40), be charged to a given potential, P (47), and let it be gradually discharged through the conductor of great resistance, r. Let the time, t, be noted at the end of which the potential of the body has fallen to p. The rate of loss of electricity will then be $\frac{p}{sr}$. Hence $p = P_{\epsilon}^{-\frac{t}{sr}}$ and $\frac{t}{sr} = \log_{\epsilon}\frac{P}{p}$. Hence

$$r = \frac{t}{s \log_{\epsilon}\frac{P}{p}}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

from which equation r can be deduced, if s, t, and the ratio $\frac{P}{p}$ be known, t can be directly observed, s can be measured (40), and the ratio $\frac{P}{p}$ can be measured by an electrometer (44) in constant connexion with the charged body. This ratio can also be measured by the relative discharges through a galvanometer, first, immediately after the body has been charged to the potential P, and again when, after having been recharged to the potential P, it has, after a time t, fallen to potential p. (This latter plan has long been practically used by Messrs. Siemens, although the results have not been expressed in absolute measure.)

Unfortunately, in those bodies, such as gutta percha and india rubber, the resistance of which is sufficiently great to make t a mensurable number, the phenomenon of absorption due to continued electrification* so complicates the experiment as to render it practically unavailable for any exact determination. The apparent effect of absorption is to cause r, the resistance of the material, to be a quantity variable with the time t, and the laws of the variation are very imperfectly known.

46. *Experimental Determination of the Ratio, v, between Electromagnetic and Electrostatic Measures of Quantity.*—In order to obtain the value of v, it is necessary and sufficient that we should obtain a common electrostatic and electromagnetic measure of some one quantity, current, resistance, electromotive force, or capacity. There are thus five known methods by which the value can be obtained.

1°. By a common measure of quantity. Let a condenser of known capacity, s, be prepared (40). Let it be charged to a given potential P (47). Then the quantity in the condenser will be sP in electrostatic measure. The charge can next be measured by discharge through a galvanometer (25) in electromagnetic measure. The ratio between the two numbers will give the value of v. The only difficulty in this method consists in the measurement

* *Vide* Transactions of British Association, 1859, p. 248, and Report of the Committee of Board of Trade on Submarine Cables, pp. 136 & 464.

of the potential P, entailing the measurement of an absolute force between two electrified bodies. This method was proposed and adopted by Weber*.

2°. By a comparison of the measure of electromotive force. The electromotive force produced by a battery, in electrostatic measure, can be directly weighed (43). Its electromotive force, in electromagnetic measure, can be obtained from the current it produces in a given resistance (28). The ratio of the two numbers will give the value of v. This method has been carried out by Professor W. Thomson, who was not, however, at the time in possession of the means of determining accurately either the absolute resistance of his circuit or the absolute value of the current†.

3°. By a common measure of resistance. We know (29 and 45) how to measure resistances in electromagnetic and electrostatic measure. The ratio between these measures is equal to v^2. The measure of resistance in electrostatic measure is not as yet susceptible of great accuracy.

4°. By a comparison of currents. The electromagnetic value of a current produced by a continuous succession of discharges from a condenser of capacity s can be measured (18, 19). The electrostatic value of the current will be known if the potential to which the condenser is charged be known. The ratio of the two numbers is equal to v.

5°. By a common measure of capacity. The two measurements can be effected by the methods given (26 and 40). The ratio between the two measurements will give v^2. This method would probably yield very accurate results.

Part V.—Electrical Measurements derived from the five elementary Measurements; and Conclusion.

47. *Electric Potential.*—The word "potential," as applied by G. Green to the condition of an electrified body and the space surrounding it, is now coming into extensive use, but is perhaps less generally understood than any other electrical term. Electric potential is defined by Prof. W. Thomson as follows‡:

"The potential, at any point in the neighbourhood of or within an electrified body, is the quantity of work that would be required to bring a unit of positive electricity from an infinite distance to that point, if the given distribution of electricity remained unaltered."

It will be observed that this definition is exactly analogous to that given of magnetic potential (10), with the substitution of the unit quantity of electricity for the unit magnetic pole. (Analogous definitions might be given of gravitation potential, heat potential, and every one of these potentials coexist at every point of space quite independently one of the other.) In another paper§ Professor Thomson describes electric potential as follows:—"The amount of work required to move a unit of electricity against electric repulsion from any one position to any other position is equal to the excess of the electric potential of the first position above the electric potential of the second position."

The two definitions given are virtually identical, since the potential at every point of infinity is zero, and it will be seen that the difference of

* Pogg. Ann. Aug. 1856, Bd. 99. p. 10. Abhandlungen der Kön. Sächsischen Gesellschaft, vol. iii. (1857) p. 266.

† Paper read before the Royal Society, February 1860. *Vide* Proceedings of the Royal Society, vol. x. p. 319.

‡ Paper read before British Association, 1852. *Vide* Phil. Mag. 1853, p. 288.

§ Paper read before the Royal Society, February 1860. *Vide* Proceedings of the Royal Society, vol. x. p. 334.

potential defined in the second passage quoted is identical with what we have called the electromotive force between the two points (16 and 27).

When, instead of a difference of potentials, *the potential* simply of a point is spoken of, the difference of potential between the point and the earth is referred to, or, as we might say, the electromotive force between the point and the earth.

The potential at all points close to the surface and in the interior of any simple metallic body is constant; that is to say, no electromotive force can be produced in a simple metallic body by mere electrical distribution; the potential *at* the body may therefore be called the potential *of* the body. The potential of a metallic body varies according to the distribution, dimensions, position, and electrification of all surrounding bodies. It also depends on the substance forming the dielectric.

In any given circumstances, the potential of the body will be simply proportional to the quantity of electricity with which it is charged; but if the circumstances are altered, the potential will vary although the total amount of the charge may remain constant.

In a closed circuit in which a current circulates, the potential of all parts of the circuit is different; the difference depends on the resistance of each part and on the electromotive force of the source of electricity, *i. e.* on the difference of potentials which it is capable of causing when its two electrodes are separated by an insulator or dielectric. The different parts of a conductor moving in a magnetic field are maintained at different potentials, inasmuch as we have shown that an electromotive force is produced in this case. The potential of a body moving in an electric field (*i. e.* in the neighbourhood of electrified bodies) is constantly changing, but at any given moment the potential of all the parts is equal. The use of the word "potential" has the following advantages. It enables us to be more concise than if we were continually obliged to use the circumlocution, "electromotive force between the point and the earth;" and it avoids the conception of a force capable of generating a current, which almost necessarily, although falsely, is attached to "electromotive force."

Equipotential surfaces and lines of force in an electric field may be conceived for statically electrified bodies; these surfaces and lines would be drawn on similar principles and possess analogous properties to those described in a magnetic field (10). It is hardly necessary to observe that the magnetic and the electric fields are totally distinct, and coexist without producing any mutual influence or interference.

The rate of variation of electric potential per unit of length along a line of force is at any point equal to the electrostatic force at that point, *i. e.* to the force which a unit of electricity placed there would experience. The unit difference of potential is identical with the unit electromotive force; and the electrometer spoken of as measuring electromotive force measures potentials or differences of potential.

48. *Density, Resultant Electric Force, Electric Pressure.*—The three following definitions are taken almost literally from a paper by Professor W. Thomson *. Our treatise would be incomplete without reference to these terms, and Professor Thomson's definitions can hardly be improved.

"*Electric Density.*—This term was introduced by Coulomb to designate the quantity of electricity per unit of area in any part of the surface of a con-

* Paper read before the Royal Society, Feb. 1860. *Vide* Proc. R. S. vol. x. p. 319 (1860), and Phil. Mag. vol. xx. Ser. 4 (1860) p. 322.

ductor. He showed how to measure it, though not in absolute measure, by his proof-plane.

"*Resultant Electric Force.*—The resultant force in air or other insulating fluid in the neighbourhood of an electrified body is the force which a unit of electricity concentrated at that point would experience if it exercised no influence on the electric distributions in the neighbourhood. The resultant force at any point in the air close to the surface of a conductor is perpendicular to the surface, and equal to $4\pi\rho$, if ρ designates the electric density of the surface in the neighbourhood.

"*Electric Pressure from the Surface of a Conductor balanced by Air.*—A thin metallic shell or liquid film, as for instance a soap-bubble if electrified, experiences a real mechanical force in a direction perpendicular to the surface outwards, equal in amount per unit of area to $2\pi\rho^2$, ρ denoting as before the electric density at the part of the surface considered. In the case of a soap-bubble its effect will be to cause a slight enlargement of the bubble on electrification with either vitreous or resinous electricity, and a corresponding collapse on being perfectly discharged. In every case we may consider it as constituting a deduction from the amount of air-pressure which the body experiences when unelectrified. The amount of deduction being different at different parts according to the square of the electric density, its resultant action on the whole body disturbs its equilibrium, and constitutes in fact the resultant electric force experienced by the body."

49. *Tension.*—The use of this word has been intentionally avoided by us in this treatise, because the term has been somewhat loosely used by various writers, sometimes apparently expressing what we have called the density, and at others diminution of air-pressure. By the most accurate writers it has been used in the sense of a magnitude proportional to potential or difference of potentials, but without the conception of absolute measurement, or without reference to the idea of work essential in the conception of potential. We believe also that it has not been generally, if ever, applied to that condition of an insulating fluid in virtue of which each point has an electric potential, although no sensible quantity of electricity be present at the point. The expression "tension" might be used to designate what we have termed the potential of a body. The tension between two points would then be equivalent to the electromotive force between those points, or to their difference of potentials, and would be measured in the same unit.

50. *Conducting Power, Specific Resistance, and Specific Conducting Power.*

Conducting Power, or Conductivity.—These expressions are employed to signify the reciprocal of the resistance of any conductor. Thus, if the resistance of a wire be expressed by the number 2, its conducting power will be 0·5.

Specific Resistance referred to unit of Mass.—The specific resistance of a material at a given temperature may be defined as the resistance of the unit mass formed into a conductor of unit length and of uniform section. Thus the specific resistance of a metal in the metrical system is the resistance of a wire of that metal, one metre long, and weighing one gramme.

The Specific Conducting Power of a material is the reciprocal of its specific resistance.

Specific resistance, referred to unit of volume, is the resistance opposed by the unit cube of the material to the passage of electricity between two opposed faces. It may easily be deduced from the specific resistance referred to unit of mass, when the specific gravity of the material is known.

Specific Conducting Power may also be referred to unit of volume. It is of course the reciprocal of the specific resistance referred to the same unit.

It is somewhat more convenient to refer to the unit of mass with long uniform conductors, such as metal wires, of which the size is frequently and easily measured by the weight per foot or metre; and it is, on the other hand, more convenient to refer to the unit of volume bodies, such as gutta percha, glass, &c., which do not generally occur as conducting-rods of uniform section, while their dimensions can always be measured with at least as much accuracy as their weights.

51. *Specific Inductive Capacity**.—Faraday discovered that the capacity of a conductor does not depend simply on its dimensions or on its position relatively to other conductors, but is influenced in amount by the nature of the insulator or dielectric separating it from them. The laws of induction are assumed to be the same in all insulating materials, although the amount be different. The name "inductive capacity" is given to that quality of an insulator in virtue of which it affects the capacity of the conductor it surrounds, and this quality is measured by reference to air, which is assumed to possess the unit inductive capacity. The specific inductive capacity of a material is therefore equal to the quotient of the capacity of any conductor insulated by that material from the surrounded conductors, divided by the capacity of the same conductor in the same position separated from them by air only. It is not improbable that this view of induction may be hereafter modified.

52. *Heat produced in a Conductor by a Current.*—The work done in driving a current, C, for a unit of time through a conductor whose resistance is R, by an electromotive force E, is $EC=RC^2$ (§ 17). This work is lost as electrical energy, and is transformed into heat. As Dr. Joule has ascertained the quantity of mechanical work equivalent to one unit of heat, we can calculate the quantity of heat produced in a conductor in a given time, if we know C and R in absolute measure. In the metrical series of units founded on the metre gramme and second, if we call the total heat Θ, taking as unit the quantity required to raise one gramme of water one degree Centigrade, we have

$$\Theta=\frac{RC^2t}{\cdot 4157}. \quad \ldots\ldots\ldots \quad (28)$$

In the British system, founded on feet, grains, seconds, with a unit of heat equal to the quantity required to raise one grain of water one degree Fahr., we must substitute the number 24·861 for ·4157 in the above equation.

53. *Electrochemical Equivalents.*—Dr. Faraday has shown † that when an electric current passes through certain substances and decomposes them, the quantity of each substance decomposed is proportional to the quantity of electricity which passes. Hence we may call that quantity of a substance which is decomposed by unit current in unit time the electrochemical equivalent of that substance.

This equivalent is a certain number of grammes of the substance. The equivalents of different substances are in the proportion of their combining numbers; and if all chemical compounds were electrolytes, we should be able to construct experimentally a table of equivalents in which the weight of each substance decomposed by a unit of electricity would be given. The electrochemical equivalent of water, in electromagnetic measure, is about 0·02 in British, 0·0092 ‡ in the metrical system. The electrochemical equivalents of all other electrolytes can be deduced from this measurement with the aid of their combining numbers.

* Experimental Researches, series xi.

† Experimental Researches, series vii.

‡ ·009375 by Weber and Kohlrausch.

54. *Electromotive Force of Chemical Affinity.*—When two substances having a tendency to combine are brought together and enter into combination, they enter into a new state in which the intrinsic energy of the system is generally less than it was before, that is, the substances are less able to effect chemical changes, or to produce heat or mechanical action, than before.

The energy thus lost appears during the combination as heat or electrical or mechanical action, and can be measured in many cases *.

The energy given out during the combination of two substances may, like all other forms of energy, be considered as the product of two factors †—the tendency to combine, and the amount of combination effected. Now the amount of combination may be measured by the number of electrochemical equivalents which enter into combination; so that the tendency to combine may also be ascertained by dividing the energy given out by the number of electrochemical equivalents which enter into combination.

If the whole energy appears in the form of electric currents, the energy of the current is measured by the product of the electromotive force and the quantity of electricity which passes. Now the quantity of electricity which passes is equal to the number of electrochemical equivalents which enter on either side into combination. Hence the total energy given out, divided by this number, will give the electromotive force of combination. Thus, if N electrochemical equivalents enter into combination under a chemical affinity I, and in doing so give out energy equal to W, either as heat or as electrical action, then

$$NI=W.$$

But if W be given out as electrical action, and causes a quantity of electricity Q to traverse a conductor under an electromotive force E, we shall have

$$W=EQ.$$

By the definition of electrochemical equivalents, E=N,

therefore $$I=E;$$

or the force of chemical affinity may in these cases be measured as electromotive force.

This method of ascertaining the electromotive force due to chemical combination, which gives us a clear insight into the meaning and the measurement of "chemical affinity," is due to Professor W. Thomson ‡.

The field of investigation presented to us by these considerations is very wide. We have to measure the intrinsic energy of substances as dependent on volume, temperature, and state of combination. When this is done, the energy due to any combination will be found by subtracting the energy of the compound from that of the components before combination.

As the tendency to increase in volume is measured as pressure, and as the tendency to part with heat is measured by the temperature, so in chemical dynamics the tendency to combine will be properly measured by the electromotive force of combination.

55.—*Tables of Dimensions and other Constants*:—

Fundamental Units.

Length=L. Time=T. Mass=M.

* Report British Association, 1850, p. 63, and Phil. Mag. vol. xxxii. Ser. 3. See papers by Prof. Andrews, and Favre and Silbermann, "On the Heat given out in Chemical Action," Comptes Rendus, vols. xxxvi. and xxxvii.

† See Rankine "On the General Law of Transformation of Energy," Phil. Mag. 1853.

‡ "On the Mechanical Theory of Electrolysis," Phil. Mag. Dec. 1851.

Derived Mechanical Units.

$$\text{Work}=\text{W}=\frac{\text{L}^2\text{M}}{\text{T}^2}. \qquad \text{Force}=\text{F}=\frac{\text{LM}}{\text{T}^2}. \qquad \text{Velocity}=\text{V}=\frac{\text{L}}{\text{T}}.$$

Derived Magnetical Units.

Strength of the pole of a magnet...... $m=\text{L}^{\frac{3}{2}}\ \text{T}^{-1}\text{M}^{\frac{1}{2}}$

Moment of a magnet ....$ml=\text{L}^{\frac{5}{2}}\ \text{T}^{-1}\text{M}^{\frac{1}{2}}$

Intensity of magnetic field .... $\text{H}=\text{L}^{-\frac{1}{2}}\text{T}^{-1}\text{M}^{\frac{1}{2}}$

Electromagnetic System of Units.

Quantity of electricity .... $\text{Q}=\text{L}^{\frac{1}{2}}\times\text{M}^{\frac{1}{2}}$

Strength of electric current .... $\text{C}=\text{L}^{\frac{1}{2}}\text{T}^{-1}\text{M}^{\frac{1}{2}}$

Electromotive force.................... $\text{E}=\text{L}^{\frac{3}{2}}\text{T}^{-2}\text{M}^{\frac{1}{2}}$

Resistance of conductor .... $\text{R}=\text{L}\ \text{T}^{-1}$

Electrostatic System of Units.

Quantity of electricity .... $q=\text{L}^{\frac{3}{2}}\ \text{T}^{-1}\text{M}^{\frac{1}{2}}$

Strength of electric currents .... $c=\text{L}^{\frac{3}{2}}\ \text{T}^{-2}\text{M}^{\frac{1}{2}}$

Electromotive force .... $e=\text{L}^{\frac{1}{2}}\ \text{T}^{-1}\text{M}^{\frac{1}{2}}$

Resistance of conductor.............. $r=\text{L}^{-1}\text{T}$

Let v be the ratio of the electrostatic to the electromagnetic unit of quantity (35 and 46); then v=310,740,000 metres per second approximately, and we have

$$q=v\text{Q} \quad \Big| \quad c=v\text{C} \quad \Big| \quad e=\frac{1}{v}\text{E} \quad \Big| \quad r=\frac{1}{v^2}\text{R} \quad \Big| \quad s=v^2\text{S}$$

Table for the Conversion of British (foot-grain-second) System to Metrical (metre-gramme-second) System.

	Number of metrical units contained in a British unit.	Log.	Log.	Number of British units contained in a metrical unit.
1° for M..............	0·0647989	$\bar{2}$·8115678	1·1884321	15·43235
2° for L, $\frac{v}{1}$, R, $\frac{1}{r}$ and V..	0·3047945	$\bar{1}$·4840071	0·5159929	3·280899
3° for F (also for foot-grains and metre-grammes).	0·0197504	$\bar{2}$ 2955749	1·7044250	50·6320
4° for W..............	0·0060198	$\bar{3}$·7795820	2·2204179	166·1185
5° for H and electro-chemical equivalents.	0·461085	$\bar{1}$·6637804	0·3362196	2·16880
6° for Q, C, and e	0·140536	$\bar{1}$·1477874	0·8522125	7·11561
7° for E, m, q, and c....	0·0428346	$\bar{2}$·6317949	1·3682051	23·3456
8° for heat	0·0359994	$\bar{2}$·5562953	1·4437046	27·7782

British System.—Relation between Absolute and other Units.

One absolute unit of $\left\{\begin{array}{l}\text{force}\\ \text{work}\end{array}\right. = 0\cdot0310666 \left.\begin{array}{l}\text{weight of a grain}\\ \text{foot-grains}\end{array}\right\}$ in London.

In London $\left\{\begin{array}{l}\text{weight of a grain}\\ \text{one foot-grain}\end{array}\right. = 32\cdot1889$ absolute units of $\left\{\begin{array}{l}\text{force.}\\ \text{work.}\end{array}\right.$

One absolute unit of $\left\{\begin{array}{l}\text{force}\\ \text{work}\end{array}\right. = \frac{1}{g} \left\{\begin{array}{l}\text{unit weight}\\ \text{unit weight} \times \text{unit length}\end{array}\right\}$ everywhere.

g in British system $=32\cdot088\ (1+0\cdot005133 \sin^2 \lambda)$, where $\lambda=$ the latitude of the place at which the observation is made.

Heat.—The unit of heat is the quantity required to raise the temperature of one grain of water at its maximum density 1° Fahrenheit.

Absolute mechanical equivalent of unit of heat $=24861=772$ foot-grains at *Manchester*.

Thermal equivalent of an absolute unit of work $=0\cdot000040224$.

Thermal equivalent of a foot-grain at Manchester $=0\cdot0012953$.

Electrochemical equivalent of water $=0\cdot02$, nearly.

Metrical System.—Relation between Absolute and other Units.

One absolute unit of $\left\{\begin{array}{l}\text{force}\\ \text{work}\end{array}\right. = 0\cdot0809821 \left.\begin{array}{l}\text{weight of a gramme}\\ \text{metre-gramme}\end{array}\right\}$ at Paris.

At Paris $\left\{\begin{array}{l}\text{the weight of a gramme}\\ \text{or metre-gramme}\end{array}\right. = 9\cdot80868$ absolute units of $\left\{\begin{array}{l}\text{force.}\\ \text{work.}\end{array}\right.$

One absolute unit of $\left\{\begin{array}{l}\text{force}\\ \text{work}\end{array}\right. = \frac{1}{g} \left.\begin{array}{l}\text{unit weight}\\ \text{unit weight} \times \text{unit length}\end{array}\right\}$ everywhere.

g in metrical system $=9\cdot78024\ (1+0\cdot005133 \sin^2 \lambda)$, where $\lambda=$ the latitude of the place where the experiment is made.

Heat.—The unit of heat is the quantity required to raise one gramme of water at its maximum density 1° Centigrade.

Absolute mechanical equivalent of the unit of heat $=4157\cdot25=423\cdot542$ metre-grammes at *Manchester*.

Thermal equivalent of an absolute unit of work $=0\cdot00024054$.

Thermal equivalent of a metre-gramme at Manchester $=0\cdot00236154$.

Electrochemical equivalent of water $=0\cdot0092$, nearly.

56. *Note to the Table of Dimensions, by Professor Clerk Maxwell.*—All the measurements of which we have hitherto treated are supposed to be made in the same medium—ordinary air; but Faraday has shown that other media have different properties. Paramagnetic bodies, such as oxygen and salts of iron, when placed in media less paramagnetic than themselves, behave as paramagnetic bodies; but when placed in media more paramagnetic than themselves, they behave as diamagnetic bodies.

Hence magnetic phenomena are influenced by the nature of the medium in which the bodies are placed, and the system of units and of measurements which we adopt depends on the nature of the medium in which our experiments are made. If we made our experiments in highly condensed oxygen, magnets would attract each other less, and currents would attract each other more, than they do in common air; and the reverse would be the case if we worked in a sea of melted bismuth.

Now if we take into account the "coefficient of magnetic induction" of the medium in which we work, and instead of assuming that of common air to be unity, assume it proportional to the density of that part of the medium to

which the magnetic action is due, we shall have the repulsion of two poles $=\frac{m\,m^1}{\mu\,r^2}$, where $m\,m^1$ are the two poles, μ the density of the magnetic medium, and r the distance. Now a density is a mass, M_1, divided by L^3, the unit of volume. Hence the dimensions of m are $\sqrt{\frac{M\,M_1}{T^2}}$; or if we can measure the density of the magnetic medium in the same unit of mass as that employed for other purposes, the dimensions of m would be simply $\frac{M}{T}$. Those of H would then be $\frac{L}{T}$, or a velocity.

If we suppose the density of the magnetic medium to be taken account of in the electromagnetic units, their dimensions become

Quantity of electricity . . $Q=L^2$, or equivalent to an area.

Strength of current . . . . $C=\frac{L^2}{T}$

Electromotive force . . . . $E=\frac{M}{T^2}$

Resistance of conductor $R=\frac{M}{L^2T}$

The electromagnetic unit of quantity of electricity is equal to the electrostatic unit multiplied by a certain velocity, depending on the elasticity of the magnetic medium, and proportional or probably equal to the velocity of propagation of vibrations in it. Hence the dimensions of

Electrostatic quantity . . . . $q=LT$

Electrostatic current. . . . . $c=L$

Electrostatic electromotive force $e=\frac{LM}{T^3}$

Resistance . . . . $r=\frac{M}{T^3}$

As we have no knowledge of the density, elasticity, &c., of the magnetic medium, we assume it as having a standard state in common air; and supposing all measurements to be made in air, the original table of dimensions is sufficient for expressing measurements made according to one system in terms of any other system.

57. *Magnitude of Units and Nomenclature.*—In connexion with the system of measurement explained in this treatise, two points hitherto unmentioned deserve attention—first, the absolute magnitude of the units, and secondly, the nomenclature.

The absolute magnitude is in most cases an inconvenient one, leading to the use either of exceedingly small or exceedingly large numbers. Thus the units of electromagnetic resistance and electromotive force and quantity, and of electrostatic currents, are inconveniently small; the unit of electrostatic resistance is inconveniently large. Decimal multiples and submultiples of these units will therefore probably have to be adopted in practice. The choice of these multiples and submultiples forms part of the business of the Committee.

The nomenclature hitherto adopted is extremely defective. In referring to each measurement, we have to say that the number expresses the value in electrostatic or electromagnetic absolute units: if a multiple is to be used, this multiple will also have to be named; and further, the standard units of length,

mass, and time have to be referred to, inasmuch as some writers use the pound and some the grain, some the metre and some the millimetre, as fundamental units. This cumbrous diction, and the risk of error imported by it, would be avoided if each unit received a short distinctive name in the manner proposed by Sir Charles Bright and Mr. Latimer Clark, in a paper read before the British Association at Manchester, 1861.

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Appendix D.—*Description of an Experimental Measurement of Electrical Resistance, made at King's College. By* Professor J. Clerk Maxwell *and* Messrs. Balfour Stewart *and* Fleeming Jenkin.

Parts I., III., and IV., by Professor Maxwell.
Part II., by Mr. Fleeming Jenkin.

Part I. *General description of the method employed.*—In the general Report of the Committee, and in Appendix C, it has already been shown that the most important aid to the exact science of electricity would be the determination of the resistance of a wire in absolute measure, and the publication of standards of resistance derived from this wire. This has already been done by Weber*; but it is desirable that the determination of a quantity so important should not be left in the hands of a single person.

Weber has employed two methods.

1st. By suddenly turning a coil of wire about an axis so as to alter its position relatively to the terrestrial magnetic lines of force, he produced an electromotive force acting for a short time in the coil. This coil was connected with another fixed coil having a magnet suspended in its centre. The current generated by the electromotive force passed through both coils and gave the magnet a sudden impulse, the amount of which was measured by its extreme deflection.

Thus an electromotive force of short duration produced a current of short duration. The total amount of electromotive force depended on the size of the moveable coil and on the intensity of terrestrial magnetism. The total amount of the current is measured by the impulse given to the magnet, and the mechanical value of the impulse is measured by the angle through which it swings. The resistance of the whole circuit, consisting of both coils, is then ascertained by dividing the electromotive force by the current.

2nd. Weber's second method consisted in causing a powerful magnet to oscillate within a coil of wire. By the motion of the magnet currents are produced in the coil, and these, reacting on the magnet, retard its motion. The rate of diminution of the amplitude of the oscillations, when compared with the rate of diminution when the circuit is broken, affords the means of determining the resistance of the circuit.

Professor W. Thomson has designed an apparatus by which the resistance of a coil can be determined in electromagnetic measure by the observation of the constant deflection of a magnet, and his arrangement has been adopted for the experiments made by the Committee.

* Pogg. Ann. Bd. 82. p. 337 (March 1851); Electrische Maasbestimmungen, Leipzig, Wiedemann; Memoirs of the Royal Society of Sciences of Saxony, vol. i. p. 197; and Phil. Mag. 1861.

The coil of wire is made to revolve about a vertical diameter with constant velocity. The motion of the coil among the lines of force due to the earth's magnetism produces induced currents in the coil which are alternately in opposite directions with respect to the coil itself, the direction changing as the plane of the coil passes through the east and west direction. If we consider the direction of the current with respect to a fixed line in the east and west direction, we shall find that the changes in the current are accompanied with changes in the face of the coil presented to the east, so that the absolute direction of the current, as seen from the east, remains always the same. If a magnet be suspended in the centre of the coil, it will be deflected from the north and south line by the action of these currents, and will be turned in the same direction as the coil revolves. The force producing this deflection is continually varying in magnitude and direction, but as the periodic time is small, the oscillations of the magnet may be rendered insensible by increasing the mass of the apparatus along with which it is suspended. The resistance of the coil may be found when we know the dimensions of the coil, the velocity of rotation, and the deflection of the magnet. The intensity of terrestrial magnetism enters into the measurement of the electromotive force, and also into the measurement of the current; but the measure of the resistance, which is the ratio of these two quantities, is quite independent of the value of the magnetic intensity.

Part II. *Description of the Apparatus.*—For convenience of description, the apparatus with which the experiments were made may be divided into five parts:—1°, the driving gear; 2°, the revolving coil; 3°, the governor; 4°, the scale, with its telescope, by which the deflections of the magnet were observed; 5°, the electric balance, by which the resistance of the copper coil was compared with a German-silver arbitrary standard.

The general arrangement of the first four parts is shown in the diagram, fig. 4, Plate VI.

The *driving gear* consisted of a leaden flywheel X on a shaft A, turned by hand, and communicating its motion by a band, $b\,b_1\,b_2\ldots.$, arranged in a way equivalent to Huyghens's gearing, to a shaft B, a pulley on which drove the revolving coil by a simple band $a\,a_1\,a_2\ldots.$ The arrangement of the band $b\,b_1\,b_2\ldots.$ communicating the motion of shaft A to shaft B may be easily understood from the diagram. C C are two guide-pulleys running loose on pins attached to the main framing. D D are two loose pulleys maintained at a constant distance by the strut E, to which the weight W is hung.

When the rotation of shaft B is opposed by a sufficient resistance, the effect of turning the flywheel in the direction shown by the arrow is to lift the weight W from the ground, tending to turn the shaft B with a definite force, which will be sensibly constant so long as the weight is kept off the ground and the band $b\,b_1\,b_2\ldots.$ remains unaltered in length. Wherever, as in the present experiments, the resistance increases with the speed of rotation, the speed of the driving-wheel can easily be regulated by hand, so as to keep the weight from falling so low as to touch the ground, or rising so high as to foul the gear, and thus, with a little care, a constant driving force can be applied to the shaft B, and to the machinery connected with it.

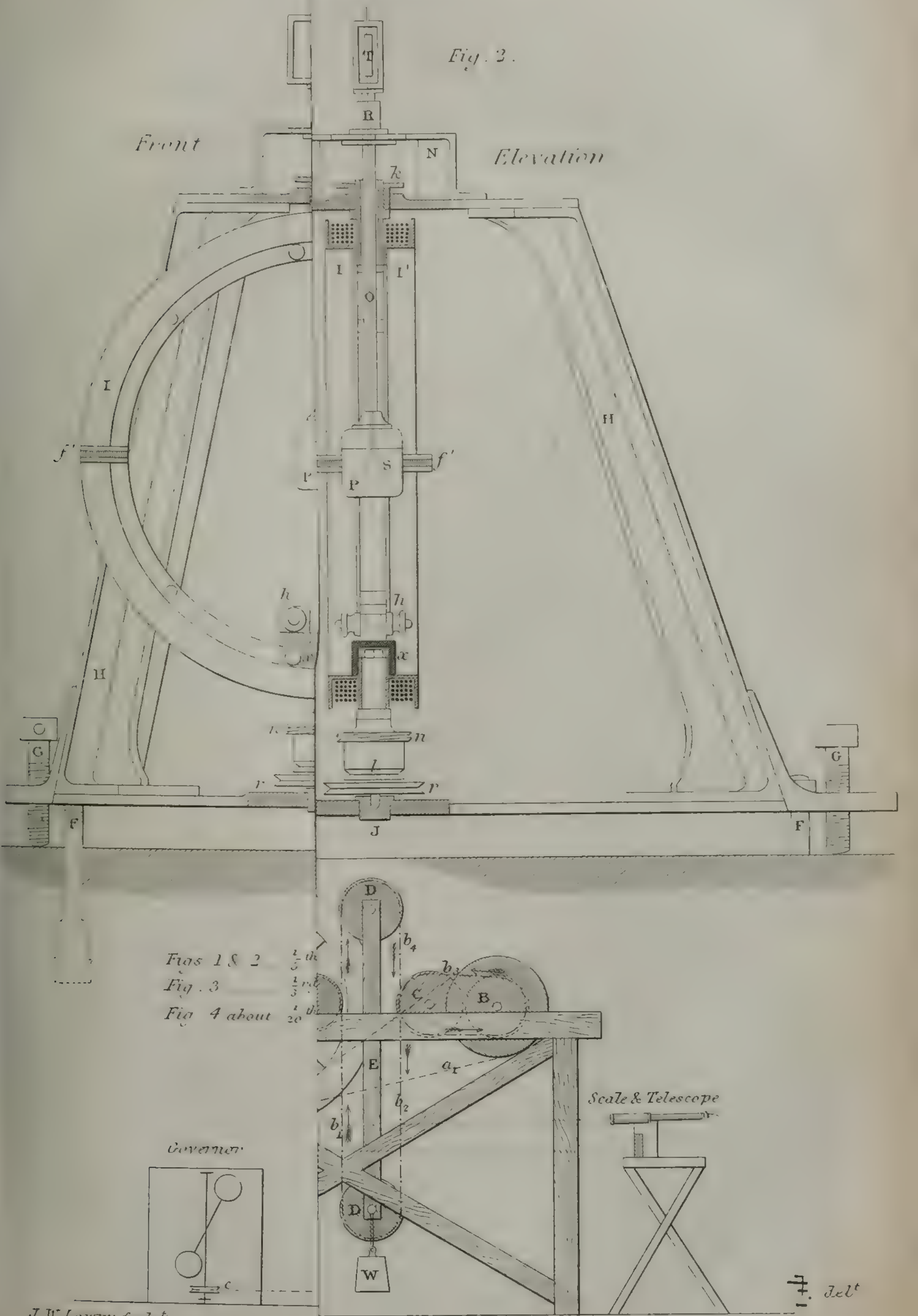
The *revolving coil* formed the most important part of the apparatus. It is shown one-fifth full size in figs. 1 and 2, Plate VI.

A strong brass frame H H was bolted down by three brass bolts F F F, dowelled into a heavy stone. It could be accurately levelled by three stout screws G G G. The brass rings I I_1, on which the insulated copper wire was coiled, were supported on the frame by a pivot J, working in lignum

ON APPARATUS,

tion of Electrical Resistance in

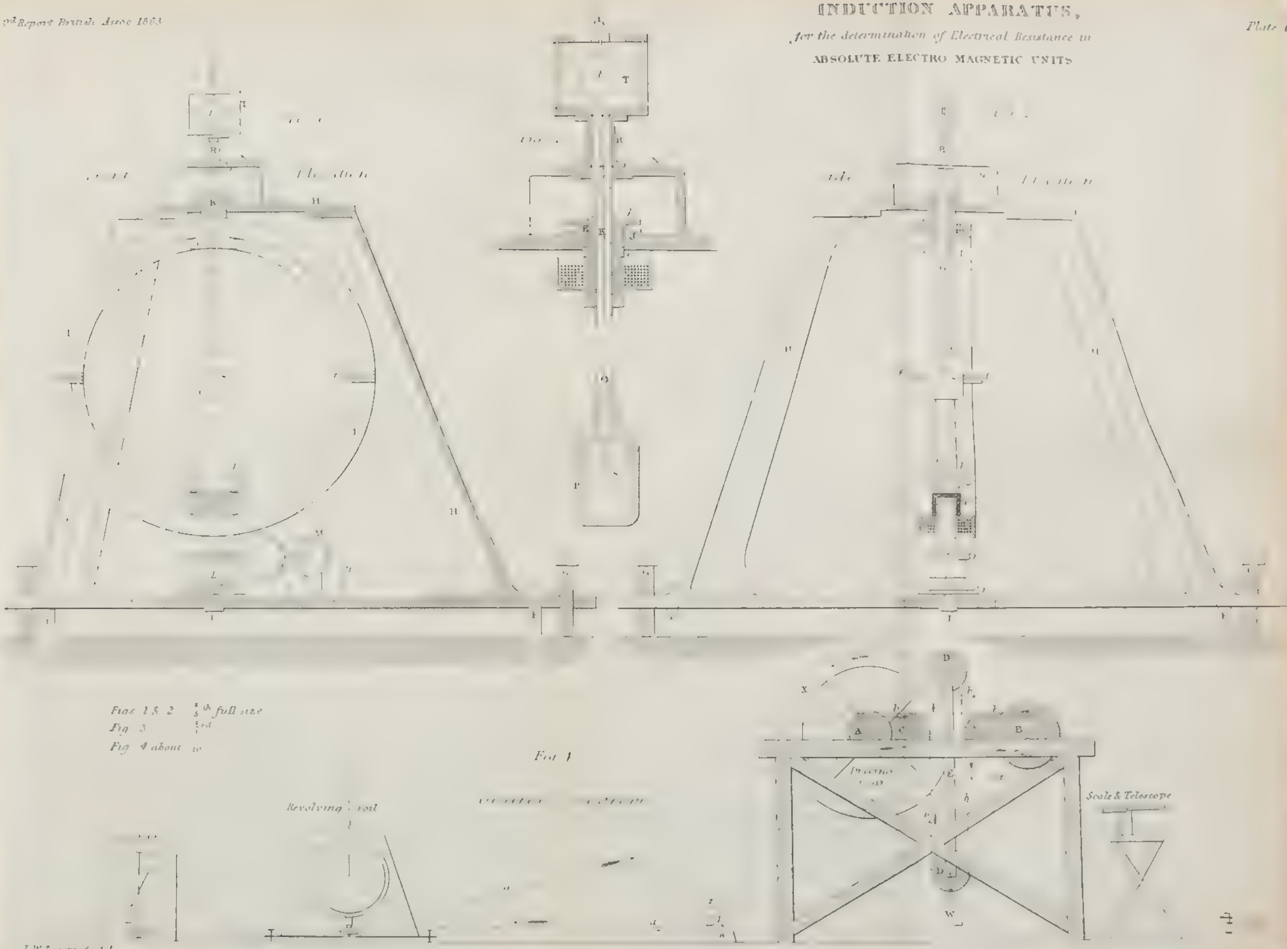
ECTRO-MAGNETIC UNITS.



INDUCTION APPARATUS,

for the determination of Electrical Resistance in

ABSOLUTE ELECTRO MAGNETIC UNITS



Figs 1 & 2 1/5th full size
Fig 3 1/3rd
Fig 4 about 1/20

J W Lowry sculp[t]

vitæ, and by a hollow bearing K, working in brass: this bearing worked in a kind of stuffing-box k (fig. 3), which by three screws and a flat spring washer between it and the frame at j, could be adjusted to fit the collar e with great nicety, preventing all tendency to bind or shake. Supported in this way the coil revolved with the utmost freedom and steadiness.

The coil of copper wire was necessarily divided into two parts on the two rings $I\,I_1$, to permit the suspension of the magnet S. The two brass rings were each formed of two distinct halves, insulated from one another by vulcanite at the flanges $f f_1$. This insulation was necessary to prevent the induction of currents in the brass rings. These rings, after being bolted together, were turned with great accuracy by Messrs. Elliott Brothers. The insulated copper wire was wound in one direction on both rings; the inner end of the second was soldered to the outer end of the first; the two extreme ends of the conductor thus formed were soldered to two copper terminals $h\,h'$, insulated by the vulcanite piece x bolted to the brass rings. Each terminal was provided with a strong copper binding screw, and had a mercury-cup drilled into its upper surface. The two coils could be joined, so as to form a closed circuit, by a short copper bar between the binding screws. The bar, binding screws, and nuts were amalgamated to ensure perfect contact. When the copper coils were to be connected with the electric balance, the short copper bar was removed and the required connexions were made by short copper rods, one quarter of an inch in diameter, dipping at one end into the mercury-cups on the terminals $h\,h'$, and at the other end into the mercury-cups of the electric balance. The absence of all induced currents influencing the suspended magnet when the circuit was broken at $h\,h'$ was repeatedly proved by experiment.

Rotation was communicated to the coils by a catgut band simply making half a turn round the small V-pulley l. The band could be tightened as required by the jockey pulley z and weight w (fig. 4).

A short screw of large diameter, n, gearing into a spur-wheel of one hundred teeth, o, formed the counter from which the speed of rotation was obtained, as follows. A pin p on the wheel o lifted the spring q as it passed; this spring in its rebound struck the gong M. The blow was of course repeated at every hundred revolutions, and the time of each blow was observed on a chronometer. The arrangement was equally adapted for rotation in either direction.

A second V-pulley r served for the band $c\,c$, communicating motion to the governor by which the speed was controlled.

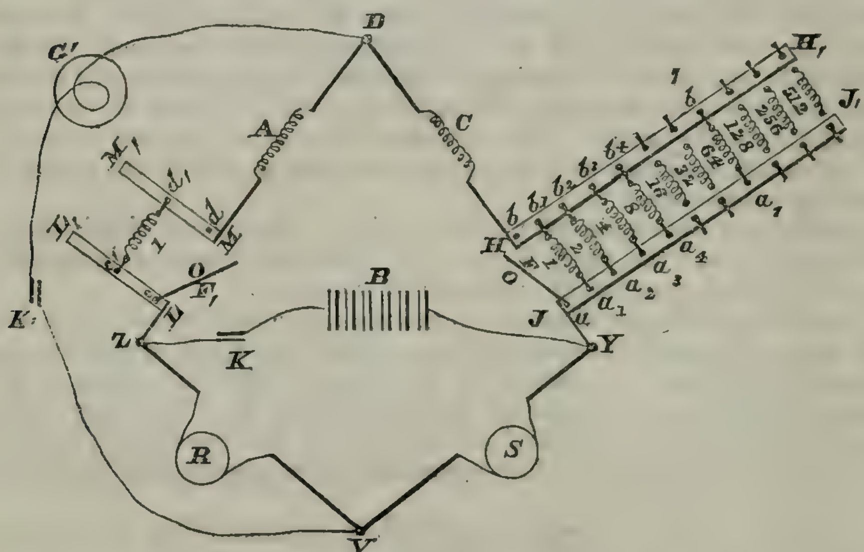
The manner in which the suspended magnet was introduced to the centre of the coil is best seen in fig. 3. A brass tripod N, bolted to the main frame, supported the long brass tube O, which passed freely through the hollow bearing at K. A cylindrical wooden box P slipped on to the end of the tube O. The magnet hung inside this box, the lower part of which could be removed to allow the exact position of the magnet to be verified. The support N also carried a short brass tube R, on which the glass case T could be secured by a little sliding tube. The mirror t, attached to the magnet S by a rigid brass wire, hung inside this glass case by a single cocoon fibre about eight feet long. This fibre was protected against currents of air by a wooden case (not shown in the Plate), extending from the point of support down to the glass case. A little sliding paper prolongation of the wooden case made it nearly wind-proof by fitting at the bottom against the main brass frame. An opening in the case allowed the mirror to be seen. The fibre at the top was suspended from a torsion head, by which it could

be turned; it could also be raised and lowered by a small barrel, and was adjustible in a horizontal plane by three set screws. The care taken in suspending the magnet and in protecting it both against currents of air and vibration was repaid by success, for the image of the scale reflected in the magnet was as clear and steady when the coil was making 400 revolutions per minute as when it was at rest.

The *governor* used was lent by one of the Committee and will not be described in detail, as an improved governor on the same principle will be adopted in future experiments, in describing which an account of its construction will be given. It may be said, however, that the little instrument actually employed generally controlled the speed to such uniformity as allowed the deflections to be observed with as much accuracy as the zero-point.

The *scale* and *telescope* hardly require special description; they were arranged in the usual manner for this kind of experiment, at about three metres from the mirror. The scale was an engine-divided paper scale nailed to a wooden bar. This plan will in future experiments be abandoned, as variations in the weather had a very perceptible influence on the scale.

The annexed diagram shows the *electric balance* by which the copper coil



C was compared with an arbitrary German-silver standard S before and after each induction experiment. The arrangement is that of the ordinary Wheatstone's balance, as described in Appendix H of the Report of your Committee for 1862. A and C represent the arms of the balance as there described, S the German-silver standard, and R the copper coil to be measured. $J J_1$, $H H_1$, $M M_1$, and $L L_1$ are four stout copper bars with mercury-cups at $a\, a_1\, a_2 \ldots$, $b\, b_1\, b_2 \ldots$, $c\, c_1$, and $d\, d_1$. Two short copper rods F and F_1 can be used to connect a with b and c with d. When this is done the arrangement is exactly that of the simple Wheatstone balance with the keys at K and K_1, as described in Appendix H of the last Report. A and C were coils formed of about 300 inches of No. 31* German-silver wire, and were adjusted to equality with extreme nicety, and each assumed equal to 100 arbitrary units. If R on any occasion had been exactly equal to S, the galvanometer G would have been unaffected on depressing the keys $K K_1$, when a was joined

* Diameter $=0{\cdot}01$ inch.

to b and c to d by F and F_1, rods of no sensible resistance. This exact equality between R and S could never be obtained, owing to slight changes in temperature which affected the two coils very differently. The object of the modifications introduced was to allow the ratio between S and R, differing by a small amount only, to be measured with great accuracy.

For this purpose a number of German-silver coils were adjusted, representing 1, 2, 4, 8 . . . . 512 in the arbitrary units, equal to the hundredth part of A or C. These coils were so arranged that any one or more of them could be introduced between the bars $H H_1$ and $J J_1$. A single coil, equal to 1 in the same arbitrary unit, could be introduced between the bars $L L_1$ and $M M_1$. In the diagram this coil is shown in its position and the rod F_1 withdrawn. Similarly F is withdrawn from between H and G, and the coil 1 joins a_1 and b_1 in the bars $H H_1$ and $J J_1$. If no other coils were placed between $H H_1$ and $J J_1$, the arms of the balance would now be 101 and 101 respectively, instead of 100 and 100; but the ratio would still be that of equality. Let us now suppose that, when the circuit with the battery is completed, the galvanometer by its deflection shows that R is bigger than S, we can reduce the resistance of the arm between D and Y by various small graduated and definite amounts by introducing the coils 2, 4, 8, &c. between $H H_1$ and $J J_1$. Let us first suppose the coil 2 introduced. The resistance between H and J will be the reciprocal of 1·5 or 0·6667; for where various resistances are added in multiple arc, the resistance of the compound arc is the reciprocal of the sum of their conducting-powers, and the conducting-power of a wire is the reciprocal of its resistance. The ratio between the two arms will now be 101 : 100·6667. Let us suppose that on completing the circuit the galvanometer still deflects in the same direction as before, the arm between D and Y must be still further reduced by including fresh coils between $H H_1$ and $J J_1$. It is very easy by trial to find the combination which maintains the galvanometer at zero when the circuit is completed. Let us suppose that, as in the diagram, the coils included were 1, 2, 4, 8, and 64. The reciprocals of these numbers are 1, 0·5, 0·25, 0·125, and 0·015625. The conducting-power between H and J is therefore 1·890625 the sum of these numbers. The resistance between H and J is 0·52893, the reciprocal of the last number, and the ratio between the arms will be 101 : 100·52893. A little consideration will show that with the coils named any ratio between 101 to 100·5, and 101 to 101 can be obtained by steps not exceeding 0·00195, the reciprocal of 512, the largest coil or smallest conducting-power which can be included between the copper bars $H H_1$ and $J J_1$. By substituting the rod F for the coil 1 between $L L_1$ and $M M_1$, the observer can obtain a fresh series of ratios with the same steps between 101 to 100 and 100·5 to 100. In this way it will be seen that unless the coils R and S differ by more than one per cent., their ratio can be measured in the manner described within 0·002 per cent.

It should further be observed that extreme accuracy in the coils 1, 2, 4, &c. is not necessary, since an error of one per cent. in the sum of these, as compared with their true relative value to the coil C, would only affect the final result 0·01 per cent.

The position of R and S in the balance relatively to A and C, &c. is of course interchangeable.

The diagram is not intended at all to represent the practical arrangement, but simply to show the connexions. The electric balance described in Appendix H of last year's Report (Plate I. figs. 1 to 6, Report 1862) was used with a stout copper rod between the cups $e\ e_1$, and two additional boards with the copper bars $H H_1$, $J J_1$, $L L_1$, and $M M_1$, fitted as in the above diagram. The

coils 1, 2, 4, &c. had amalgamated copper terminals which simply dropped into mercury-cups on the copper bars. The observations could be made very rapidly and accurately, as the galvanometer was sensitive enough with four Daniell's cells to indicate the addition or subtraction of the 512 coil with perfect distinctness. The reduction of the observations to find the ratio seems somewhat complicated at first, but with the aid of a table of reciprocals it takes but little time. No improvement seems necessary in this part of the apparatus. The idea of using large coils combined with small ones in multiple arc to obtain extremely minute differences of resistance, was suggested to the writer by Professor W. Thomson, and will be found useful in very many ways.

Part III.—Mathematical Theory of the Experiment.

A circular coil of copper wire is made to revolve with uniform velocity about a vertical diameter. A small magnet is suspended by a silken fibre in the middle of the coil. Its position is observed when the coil is at rest, and when the coil revolves with velocity ω the magnet is deflected through an angle ϕ. Currents are induced in the coil by the action of the earth's magnetism, and these act on the magnet and deflect it from the magnetic meridian. By observing the deflection and the velocity of rotation, we can determine the resistance of the coil in electromagnetic units.

In determining the strength of the current we may neglect the motion of the suspended magnet, as it is found, both by theory and by experiment, to be insensible. We have therefore, in the first place, to determine the electromagnetic potential of the coil with respect to the earth's magnetism, with respect to the suspended magnet, and with respect to itself.

1st. Let H be the horizontal component of the earth's magnetism.
γ the strength of the current in the coil.
G the total area enclosed by all the windings of the wire.
θ the angle between the plane of the coil and the magnetic meridian.

Then the potential of the coil with respect to the earth is

$$-\mathrm{H}\gamma\mathrm{G}\sin\theta.$$

2nd. Let M be the magnetic moment of the suspended magnet.
ϕ the angle between the axis of the magnet and the magnetic meridian.
K the magnetic force at the centre of the coil due to unit current in the wire.

Then the potential of the coil with respect to the magnet is

$$-\mathrm{M}\gamma\mathrm{K}\sin(\theta-\phi).$$

3rd. Let $\frac{1}{2}$L be the potential of the coil on itself for unit current.
Then the potential due to a current γ is

$$\tfrac{1}{2}\mathrm{L}\gamma^2.$$

Let P be the electromotive force, and R the resistance, then the work spent in keeping up the current is Pγ in unit of time; or, since $\mathrm{P}=\mathrm{R}\gamma$, the work spent in keeping up the current for a time δt is

$$\mathrm{R}\gamma^2\,\delta t.$$

If the current is at the same time increased from γ to $\gamma+\delta\gamma$, the work spent in increasing the current will be

$$\mathrm{L}\gamma\,\delta\gamma.$$

If the angular motion of the coil be $\delta\theta$, the work spent in keeping up the rotation against the electromagnetic force is

$$H\gamma G\cos\theta d\theta + M\gamma K\cos(\theta-\phi)\,d\theta.$$

Since this work is exactly consumed in keeping up or increasing the current, we must have

$$H\gamma G\cos\theta d\theta + M\gamma K\cos(\theta-\phi)d\theta = R\gamma^2\,dt + L\gamma d\gamma.$$

Since $\theta=\omega t$ and $\frac{d\theta}{dt}=\omega$, the solution of this equation is

$$\gamma=\frac{\omega}{R^2+L^2\omega^2}\{GH(R\cos\theta+L\omega\sin\theta)+KM\left(R\cos(\theta-\phi)+L\omega\sin(\theta-\phi)\right)\}$$
$$+C\epsilon^{-\frac{R}{L}t},$$

the last term becoming insensible soon after the beginning of the experiment.

We can now find the equation of motion of the magnet.

Let A be its moment of inertia, $MH\tau$ the torsion of the fibre per unit of angular rotation, then

$$A\frac{d^2\phi}{dt^2}=MK\gamma\cos(\phi-\theta)-MH(\sin\phi+\tau\phi).$$

Substituting the value of γ and separating terms in θ, we find

$$A\frac{d^2\phi}{dt^2}=\frac{1}{2}\frac{MK\omega}{R^2+L^2\omega^2}\left\{GH(R\cos\phi+L\omega\sin\phi)+KMR\right\}-MH(\sin\phi-T\phi)$$
$$+\frac{1}{2}\frac{MK\omega}{R^2+L^2\omega^2}\left\{GH\left(R\cos(2\theta-\phi)+L\omega\sin(2\theta-\varphi)\right)\right.$$
$$\left.+KM(R\cos 2(\theta-\phi)+L\omega\sin 2(\theta-\phi))\right\}.$$

In order that ϕ may continue as it does nearly constant, the part independent of θ must vanish, or

$$\frac{1}{2}\frac{MK\omega}{R^2+L^2\omega^2}\left\{GH(R\cos\phi+L\omega\sin\phi)+KMR\right\}-MH(\sin\varphi+T\phi)=0.$$

This gives the following quadratic equation for R,

$$R^2-\frac{1}{2}R\frac{GK\omega}{\sin\phi+\tau\phi}\left(\cos\phi+\frac{KM}{GH}\right)=\frac{1}{2}\frac{GKL\omega^2}{1+\tau\frac{\phi}{\sin\phi}}-L\omega^2.$$

The solution of this equation may be expressed to a sufficient degree of accuracy as follows:—

$$R=\frac{GK\omega}{2\tan\varphi(1+\tau)}\left\{1+\frac{KM}{GH}\sec\phi-\frac{2L}{GK}\left(\frac{2L}{GK}-1\right)\tan^2\phi\right\}.$$

To determine the quantities occurring in this equation, we must measure the dimensions of the coil, the strength of the magnet, and the force of tension of the fibre.

1st. Dimensions of the coil.

Let a = mean radius of the coil .... = 0·1566 metre.
n = number of windings of wire .... = 307
l = effective length of wire $=2\pi na$ .... = 302·063 metres.
b = breadth of section of coil perpendicular to the plane of the coil .... = ·0185 metre.

c=depth of section in the plane of the coil ......= ·0132 metre.
b'=distance of mean plane of coil from axis of motion ....= ·01915 „
α=angle subtended at axis by radius of coil=83° 1′.

$$\cos\alpha=\frac{b'}{a}=\cdot12245\,;$$

Then $G=\pi na^2\left(1+\frac{1}{12}\frac{c^2}{a^2}\right)$,

$$K=\frac{2\pi n}{a}\sin^3\alpha\left\{1+\frac{1}{24}\frac{c^2}{a^2}(2-15\sin^2\alpha\cos^2\alpha)\right.$$
$$\left.+\frac{1}{24}\frac{b^2}{a^2}(15\sin^2\alpha\cos^2\alpha-3\sin^2\alpha)\right\},$$

$$GK=\pi nl\sin^3\alpha\left\{1+\frac{1}{6}\frac{c^2}{a^2}+\frac{5}{8}\frac{b^2-c^2}{a^2}\sin^2\alpha\cos^2\alpha-\frac{1}{8}\frac{b^2}{a^2}\sin^2\alpha\right\}.$$

If the dimensions of the coil are measured in metres, GK will be expressed in metres.

Let T be the time of 100 revolutions of the coil, expressed in seconds, then

$$T\omega=200\pi,$$

or

$$\omega=\frac{200\pi}{T}.$$

Let D be the distance of the scale from the mirror, δ the scale-reading measured from the point of the scale which is nearest to the mirror, then

$$\tan 2\phi=\frac{\delta}{D};$$

$$\therefore\frac{1}{2\tan\phi}=\frac{D}{\delta}\left\{1+\frac{1}{4}\frac{\delta^2}{D^2}\right\}.$$

To determine MHτ, the coefficient of torsion, let the magnet be turned round so as to twist the fibre nearly 360°. Let the difference of reading due to the torsion be δ', then

$$\tau=\frac{\delta'}{4\pi D}\frac{1}{1-\frac{\delta'}{4\pi D}}.$$

To determine $\frac{KM}{GH}$, let the suspended magnet A be removed, and let another magnet, which we shall call B, be put in its place. Let the magnet A be now placed east or west of B, at a distance equal to the mean distance of the coil, or $\sqrt{a^2+b'^2}$. Let the deflection of B when the north or south end of A is directed to it be μ, then

$$\frac{KM}{GH}=\tan\mu.$$

The determination of the quantity L, the electromagnetic capacity of the coil, requires a more complex calculation which must be explained separately. In the actual experiment the deviation ϕ was always small, and therefore $\tan^2\phi$ was very small, so that the term depending on L was never important.

We may now write the value of R,

$$R=\frac{200\pi^2 Dnl\sin^3\alpha}{T\delta}\{1+\text{corrections}\}.$$

In this expression the quantities $Dnl\alpha$ are determined before the experiment is made. The only quantities to be observed are T, the number of seconds in 100 revolutions, and δ, the deviation in millimetres of the scale.

Part IV.—Details of the Experiments.

In the experiments at King's College, June 1863,

n, the number of windings, was 307.

l, the effective length of wire, 302·063 metres.

$\sin^3\alpha=1-{\cdot}021756$.

D, the distance from the mirror to the scale, 2·9853 metres.

Determination of Velocity.

A wheel of 100 teeth turned by an endless screw caused a bell to be struck every 100 revolutions of the coil. The times of the bells, as observed with a chronometer, serve to determine T.

Determination of Deviation.

δ is the difference between the reading of the scale when the magnet is acted on by the earth only, and when it is acted on also by the induced currents in the coil. To determine δ, the reading of the scale is made when the coil is at rest, or when the circuit is broken. Another reading is taken with the connexion complete and the coil in motion. If the earth's magnetism remains the same, the difference of these readings is the true value of δ; but since the direction of the earth's magnetic action is continually varying, we must find the difference of *declination* between the times of the two readings, and calculate what would have been the undisturbed reading of the scale at the time when the deviation was observed.

In our experiments this correction was made by comparison with the photographic registers of magnetic declination made at Kew at the same time that our experiments were going on.

Corrections.

The corrections being small may be taken separately. Each has to be multiplied by the factor already considered,

$$R=\frac{200\pi^2 Dnl\sin^3\alpha}{T\delta}\{1+A+B+C+D+E+F+G+H+\&c.\}.$$

A. Correction for the dimensions of the section of the coil.

$$A=\frac{1}{6}\frac{c^2}{a^2}+\frac{5}{8}\frac{b^2-c^2}{a^2}\sin^2\alpha\cos^2\alpha-\frac{1}{8}\frac{b^2}{a^2}\sin^2\alpha$$
$$=+{\cdot}000075.$$

B. Correction for level. Let the axis of rotation be inclined to the vertical at an angle β measured towards the north, and let the angle of the dipping-needle with the horizontal be I, then there will be a correction,

$$B=-\tan I\sin\beta.$$

In the actual experiment the level was taken with a spirit-level reading to 12″, and found correct to at least that degree of accuracy.

C. Correction for the induction of the suspended magnet on the coil. The strength of the magnet, as compared with that of the magnetic field, was mea-

sured by means of a magnetometer from Kew by the ordinary method. The correction found was

$$C=+\tan\mu$$
$$=\cdot 00780.$$

The small magnet generates induction currents in the coil which react on the magnet, and tend to turn it in the direction in which the coil revolves. If there were no horizontal magnetic force due to the earth, the coil would drag the magnet round after it. In the actual case it makes the deviation greater than it should be by ·0078.

D. Correction for torsion of the fibre

$$D=-T=-\frac{\delta'}{4\pi D}$$
$$=-\cdot 00132.$$

This correction depends on the relation between the stiffness of the fibre and the directive force of the suspended magnet. The fibre was a single fibre of silk 7 feet long; the magnet was a steel sphere $\frac{5}{16}$ inch diameter, and not magnetized to saturation. The correction for torsion was therefore much larger than if a stronger magnet had been used.

E. Correction for position of suspended magnet.

Let the centre of the magnet be at a distance ζ above or below the centre of the coil, η north or south of the axis of motion, and ξ east or west of the axis, then there will be a correction,

$$E=+\frac{3}{16}(1-4\cot^2\alpha)\sin^4\alpha\left\{4\frac{\zeta^2}{a^2}-\frac{\eta^2}{a^2}-3\frac{\xi^2}{a^2}\right\}.$$

Here $a=156\cdot 6$ millimetres, and the place of the magnet was so adjusted that it could not vary one millimetre in any direction without the error being observed. Hence this correction is negligible.

F. Correction for irregularity in the magnetic field due to iron or magnets near the instrument.

Let t be the time of oscillation of a magnet at the centre of the coil t_1, and t_2 at distances z above and below that point, then

$$F=+\frac{3a^2}{16z^2}\left\{\frac{2t-(t_1+t_2)}{t}\right\}.$$

This correction may also be neglected.

G. Correction of scale-reading. The quantity observed is $\tan 2\phi$, the quantity to be found is $\tan\phi$. The correction to the value of R is

$$+\frac{1}{4}\frac{\delta^2}{D^2}.$$

H. Correction for electromagnetic capacity of the coil.

Let L be the value of the electromagnetic capacity, the correction is

$$-\frac{1}{4}\frac{\delta^2}{D^2}\frac{2L}{GK}\left(\frac{2L}{GK}-1\right).$$

In the actual coil L was found by calculation $=397750$ metres, and by a rough experiment $=398500$ metres.

Now $GK=560245$ metres.

The correction is therefore $-\frac{1}{4}\frac{\delta^2}{D^2}(0\cdot 596234)=H.$

This correction is of the same form with G, and may be taken along with it.

The complete expression for R is therefore

$$R=\frac{1}{T\delta}538145581730+\frac{\delta}{T}3055\cdot5.$$

The nature of the electrical action in the experiment may be stated as follows:—

Suppose the plane of the coil to coincide with magnetic north and south, and that the coil is revolving in the direction of the hands of a watch. Then the north side of the coil is moving from west to east, and therefore experiences an electromotive force tending to produce an *upward* current. The south side of the coil is moving from east to west, and therefore there is a tendency to produce a downward current in it. If the circuit is closed there will be a current upwards on the north side, and downwards on the south side round the coil.

Now this current will tend to turn the north end of the suspended magnet towards the east. But the earth's magnetic force tends to turn it towards the north, so that the actual position assumed by the magnet must depend on the relation between the strength of the current and the strength of the earth's magnetism. But the strength of the current depends only on the velocity of rotation, the resistance of the coil, and the strength of the earth's magnetism. Hence the position of the magnet will not depend on the strength of the earth's magnetism, but only on the velocity and the resistance of the coil.

We must remember that the coil in its revolution comes into other positions than that which we have mentioned. As the north side moves towards the east, the current continually diminishes till it ceases when it is due east. The current then commences in the opposite direction with respect to the coil; but since the coil itself is now in a reversed position, the effect of the current on the suspended magnet is still to turn the north end to the east. The action of the current on the magnet is therefore of an intermittent nature, and the position of the magnet is not fixed, but continually oscillating. The extent of these oscillations, however, is exceedingly small. In fact, if T be the time of vibration of the magnet from rest to rest under the action of the earth, and if t be one quarter of the time of revolution of the coil, and if δ be the deviation as read on the scale, then the same amplitude of these oscillations will be

$$c=\frac{t^2}{T^2}\delta.$$

In the actual experiment $\frac{t}{T}=$about $\frac{1}{200}$, and δ less than 400 millimetres, so that the whole extent of vibration would be less than $\frac{1}{100}$ of a millimetre on the scale. This vibration was never observed and did not interfere with the distinctness of vision.

The only oscillations observed were the free oscillations of the magnet. They arose from accidental causes at the beginning of the experiment, and were subject to slight alterations in magnitude due to changes of speed of rotation, the passage of iron steamers in the Thames, &c. The time of one vibration was about 9·6 seconds, and by reading the scale at the extremities of every vibration a series of readings was obtained, the intervals between which were approximately equal.

Now since the deviation is proportional to the velocity

$$\delta=Cv=C\frac{dx}{dt},$$

and if we take values of δ at small intervals dt and sum them, we shall get

$$\int\delta.dt = \mathrm{C}\int v\,dt = \mathrm{C}x,$$

where x is the whole distance travelled in the time.

Hence all we have to do is to observe the deviation at every oscillation, and to ascertain the whole number of revolutions during the time of observation, and the exact beginning and ending of that time. This was done in the following way.

The coil was made to revolve by means of the driving machine, and its velocity was regulated by the governor. While the required velocity was being attained, the oscillations of the magnet were reduced within convenient limits by means of a quieting bar at a distance. The quieting bar was then put in its proper place and the observation commenced.

One observer, A, took the readings of the scale as seen in the telescope, writing down the deviation at the extremity of every oscillation, and thus obtaining a reading every 9·6 seconds.

Another observer, B, with a chronometer, wrote down the times of every third stroke of the bell. The times thus found were at intervals of 300 revolutions. When the observer B noted the time, the observer A made a mark on his paper, so that after the experiment the readings of deviation could be compared with the readings of the chronometer taken at the same time.

The mean time of revolution between any two times of observation could thus be found and compared with the mean deviation between the same limits of time, and any portion of an experiment accidentally vitiated could be rejected by itself.

The experiments of each day commenced with a comparison by means of an electric balance* between the resistance of the experimental coil and that of a German-silver coil (called "June 4").

Then a series of readings of the scale was taken to determine the undisturbed position of the magnet. The times of beginning and ending this series were noted, and called Times of 1st Zero.

Then the coil was made to revolve, and readings of deviation and of time were taken as already described, and called 1st Spin +.

Then the direction of rotation was reversed and a second set of readings obtained, and called 2nd Spin −.

Then the undisturbed position was again observed with a note of the time. This was called 2nd Zero.

Lastly, the resistance was compared again with the standard coil. This series of experiments was then repeated if there was time.

From the values of 1st zero and 2nd zero, together with the information obtained from the photographic registers at Kew, the true value of the undisturbed reading during the 1st spin and 2nd spin was obtained. The difference between this and the actual reading is the deviation δ due to the electric currents. T was got by the chronometer readings. Now let r be the resistance of the standard coil at standard temperature, R the resistance of the experimental coil during the experiment, then by the comparison of resistances we find

$$\mathrm{R} = xv,$$

where x is the ratio observed by means of the electric balance. But we also

* *Vide* Report, 1862, p. 159, and present Appendix, p. 166.

know that $R=\frac{N}{T\delta}+\text{correction}$, where N is a known number given at p. 146. Hence r, the resistance of the standard coil, may be found in absolute measure by the formula

$$r=\frac{N}{x T\delta}+\text{a small correction};$$

the value of $xT\delta$ should therefore be nearly constant.

Thus, on June 23rd, 1863, the experiments were made as follows:—

At $12^h\ 15^m$ the resistance of the copper experimental coil was compared with that of standard coil "June 4" taken at 101, and found to be 101·26.

From $12^h\ 36^m$ to $12^h\ 45^m$ the undisturbed position of the suspended magnet was observed, and found to be 590·28 scale-divisions as the mean of all the readings.

The position of the declinometer at Kew at the same time was 7·689 of its own scale-divisions.

From $12^h\ 47^m\ 51^s{\cdot}5$ to $1^h\ 3^m\ 13^s$ the position of the magnet was again observed while the coil was revolving; 104 readings of the scale were taken, of which the mean was 930·59. This, when corrected for scale-error, gives 931·48 as the true reading. The position of the declinometer at Kew during the same time was 7·679. The resistance, measured after the experiment, was 101·28.

The number of revolutions was 6300 during the time of observation, so that the time of 100 revolutions was $14^s{\cdot}464$.

By comparing the Kew apparatus with that at King's College, it appears that 1·0 of the Kew scale=19·137 of the King's College scale. The undisturbed readings at King's College were found actually to vary very nearly in this proportion to those at Kew.

Hence it is easy to find the undisturbed reading during any given experiment by comparison with the Kew numbers.

Thus, for the first experiment on 23rd June we get

Corrected undisturbed reading		591·54
Deflected reading		931·48
Deflection δ	=+	339·94
Time of 100 revolutions=T	=	14·464
Product $T\delta$	=	4916·90
Resistance at time of experiment x	=	101·28
$T\delta x$	=	4979·75

Three other experiments were made on June 23rd. The result of the four experiments was as follows:—

1st experiment.	Positive Rotation....	$T.\delta.x$	=4979·75
2nd „	Negative	$T.\delta.x$	=5071·18
3rd „	Positive............	$T.\delta.x$	=5093·35
4th „	Negative	$T.\delta.x$	=5007·66
Mean Positive result			5036·55
Mean Negative result.....................		....	=5039·42
Mean result of June 23rd...........			5037·98
Mean result of June 19th...........			5075·77
Mean result of June 16th...........			5046·18
Mean of three days			5053·32

It will be observed that the mean results of each day are more concordant than the individual experiments made on the same day. The errors, therefore, which we have hitherto been unable to get rid of are not of a kind which would have the effect of making the result depend on the arrangements adopted on the day of experiment, but are rather such as would destroy one another in any long series of experiments.

Dividing N by the number just found, we get for the resistance called 100 provisionally, $106493470+61100=10655470$,

the second term being the correction for self-induction and for scale-reading.

Since the coil of German silver, marked June 4th, was called provisionally 101, we find as the result of the experiments for the resistance of "June 4" in absolute measure

107620116 metres per second.

Knowing the absolute resistance of "June 4," we may construct coils of given resistance by known methods.

Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations of India. By Edward Smith, *M.D., LL.B., F.R.S., Fellow of the Royal College of Physicians, Assistant Physician to the Hospital for Consumption at Brompton, &c.*

The Meeting of the British Association held at Manchester in 1861 requested Dr. John Davy and myself to represent to the Secretary of State for India the advantage which would accrue to science if a Report were obtained on the dietary of jails throughout India, on the plan pursued by Dr. Mouat in his Report on the jails in Lower Bengal. The Secretary of State was pleased to accede to this request, and during the early part of the year 1863 copies of the Report so obtained were courteously sent to me, and probably to others interested in the matter; and as so valuable a collection of facts could not be duly appreciated by the members of the British Association in the voluminous form in which they were presented, I thought it might add to the service which the Report will render if I prepared an abstract of it which should contain the most important facts. My proposition to do this was accepted by the Meeting of the British Association held at Newcastle in 1863, and it was directed that the abstract should be printed amongst the Reports *.

The Report contains information from more than one hundred military and civil surgeons, and comprehends the districts of Bengal, the North-western Provinces, the Punjab, Oude, and British Birmah. Some of these reports are of considerable length, and offer much information on the natural history,

* Whilst preparing this abstract, I have been much impressed with the desirability, I may almost say the necessity, of a calculation being made of the nutritive elements contained in the following extensive series of dietaries, since, without this, the reports are of comparatively little value, and may be likened to a bill of parcels with the prices omitted; but as the calculations would have occupied fully a month, I felt that it would not be just to myself to undertake them, in addition to the great labour necessarily involved in abstracting upwards of 100 reports; and, moreover, so important a public service should be performed under the direction of some department of the Government. It is a curious coincidence that the medical department of the Privy Council has, during the present year, desired me to make a similar inquiry in reference to the British Islands; and these are the only serious attempts which have been made in any country to determine the nature and nutritive value of the national dietary. The absence of the calculations just referred to renders the Indian returns valueless for comparison with the British inquiries.

preparation, and use of foods, with descriptions of the several classes and castes of the people and their habits with regard to dietary. Many give explicit answers to one of the questions which seem to have been proposed to the writers, viz. the daily diet of an adult labourer; but many, unfortunately, omit this return altogether; whilst others mention the quantity of the several foods which would be eaten daily, when used, but do not select, out of the number referred to, those articles which together constitute the daily dietary. Hence, whilst much physiological, botanical, ethnological, and social information has been given by the reporters when thus left to their own discretion, it is certain that an exact form of report upon this essential question of the daily dietary would have added greatly to the value of the inquiry. In abstracting the returns, I have almost limited myself to the two questions upon which information was especially desired—the food and daily dietaries of the free and imprisoned populations; but have added information respecting the inhabitants, and their selection and preparation of food, with the effect of this food on their health and strength. When the remarks were important, I have usually stated them almost in the words of the reporters. As there are great numbers of both vegetable and animal foods the names of which are unknown here, I have seldom transcribed them; and in reference to weight, I have given them in English ounces and pounds, reckoning 1 seer = 2 lbs., and 1 chittak = 2 ozs., except in two or three localities where the weight was stated to differ from that standard.

The reports in reference to jail dietaries have been obtained at an unfortunate period, since a new scheme of jail dietary was promulgated by Dr. Mouat in 1862, and time had not been given to ascertain its effect. Several schemes have been devised and ordered to be adopted within the last twelve years: viz., the old scale, 1857; the Medical Board scale; Mr. Lock's scale, 1854; Dr. Mouat's scale, 1858; another scale, 1860; and Dr. Mouat's new scale, in 1862. When the new scale had been adopted at any jail, I have not considered it necessary to quote the older ones, or to refer to their effect upon the prisoners. The tables which are issued with the different reports have a formidable appearance to the reader; but, on careful scrutiny, I find that they may be referred to about twenty-five types, and I have arranged them in an Appendix, and referred to them by number at the end of each report.

Bengal.—Dacca Circle.

1. Dr. H. M. Davies, of Noakhally, states that rice is the principal food in use, and that it is eaten with dal (leguminous seeds), chillies, garlic, onions, and other vegetables, as cucumbers, melons, plantains, beans, and pulse, with fish and milk and flesh occasionally. All are usually boiled together and made into curry. The food is of low nutritive quality, and the inhabitants are not robust. He gives the dietary at Noakhally Jail. (Diet No. 1 in the Appendix.)

2. Dr. R. C. Chandra, of the district of Tipperah, states that rice is the staff of life, and is eaten twice or thrice a day, in a total quantity of 1 to $1\frac{1}{4}$ seer = 32 ozs. to 40 ozs. The two ordinary meals are taken at 10 or 11 A.M. and after sunset, whilst the third, when eaten, is taken early in the morning, before going to work. Vegetables are made into curry and eaten once a day. Fish, fresh or salted, is eaten twice or thrice a week. Dal is rarely eaten —only five to seven times a month. Meat (fowl, beef, and goat) is rarely eaten by Hindoos, and only eight or ten times a month by Mahomedans. The condiments are mustard-oil, salt, ginger, turmeric, and chilli; and among the Mahomedans, onions and garlic, vegetable acids, and mangoes. Indian

plum and tamarinds are eaten eight or ten times a month. There is but little nitrogen in the food, but it is sufficient. The spare use of dal and vegetable acid is significant. He gives the dietary at the jail, divided into that of the labouring and non-labouring classes, and remarks that it is sufficient in quantity, but deficient in quality. Dal is given too often, as it is difficult of digestion and causes bowel-complaint. There is a deficiency of vegetable acid. (Diet No. 13.)

3. Dr. R. Bunbury, of Mymensing, states that at the early morning, mid-day, and evening meals from 2 lbs. to 3 lbs. of rice is eaten, with dal 4 ozs. to 8 ozs., fish from 2 ozs. to 1 lb., vegetables (foliaceous or succulent) 4 ozs. to 8 ozs., oil or ghee, with various condiments. The very poor eat 3 lbs., and others 4 lbs. to 8 lbs., of solid food daily. Dal produces bowel diseases, and fish cutaneous or bowel diseases, particularly on the eastern side of the district, where 1 lb. of fish is eaten daily. He gives the jail dietary, both old and new, and states that less than the ordinary quantity, but more than the ordinary quality, of food is needful in confinement. Prisoners, when young and robust, lose weight after a few months' incarceration; and the quality (animal food) does not restore the loss. (Diet No. 1.)

4. Dr. A. Simpson, of Dacca, states that $1\frac{1}{2}$ lb. to 2 lbs. of rice (8 kinds) is required at each of the meals. It is simply boiled, when it is called *bhât*, or is prepared into *choora*, *mooree*, *khoi*, or *moorkee*; but *bhât* is the only wholesome form as a daily food. Rice should be kept three years before it is used, as, when new, it is not easily digestible, and causes dyspepsia and diarrhœa. Dal (7 kinds) 8 ozs., or 1 poa, are eaten daily. It is boiled with turmeric until it is quite soft, when condiments are added, and it is eaten with rice or bread. Dals are very nutritious, but differ in digestibility. They grow and are used universally in the district, and the cost varies from 1 anna to 2 pice per 2 lbs. Barley is rarely used, except on the last day in the year, when it is parched and finely powdered, and 8 to 24 ozs. eaten: it is digestible and nutritious, and is sold in the husk at from 12 annas to 1 rupee per maud. Wheat is eaten chiefly by natives of the Upper Provinces, and is imported from Malda and Patna. Fine flour, costing 2 annas per 2 lbs., is made into sweetmeats and fermented or unfermented bread. The only baked bread of the Hindoos is prepared at home, and is the *chapattee*; it is made into small biscuits, and eaten, when hot, with *ghee* or clarified butter. The rich Hindoos eat another preparation, *malpooah*. In the towns both Hindoos and Mahomedans eat two principal meals, consisting of rice, fish, and curries, the Mahomedans eating meat also, whilst bread and *mithias* (sweetmeats) are eaten between meals. He mentions twenty-one kinds of vegetables, besides leaves, stalks, and fruits (including potatoes, cabbage, cauliflower, lettuce, turnips, carrots, beetroot, celery, radishes, French beans, cresses, &c.), of which about 8 ozs. are eaten at a meal. They are generally digestible and nutritious; they grow in the district, and cost 1 pice to 1 anna per 2 lbs. He gives the mode of cooking. Forty-five kinds of fish, with cow's, buffalo's, and goat's milk, and various kinds of meat, eggs, and game, are quoted; and of these about 8 ozs. are taken at the two meals. Fish is fried in oil, with condiments, and added to the prepared vegetables. Milk is eaten simply boiled, or boiled until it becomes a semi-solid mass; or is curdled by heat or acid, and eaten with the curd separated or otherwise. Butter is generally made from the *douhee* (milk curdled with acid), and sometimes from milk; it is rarely eaten by the natives, who prefer ghee or clarified butter, and fry their food in it. *Shor* or *malai* is milk kept at a low heat for six hours, until the cream rises (as in making the clotted cream in Devon). Hindoos

may eat only the flesh of the he-goat offered to some god or goddess. They eat pigeons and ducks occasionally, and turtle during the two first months of the cold season. They also eat ducks' and turtles' eggs, but not fowls' eggs. The Mahomedans eat all kinds of meat, except that of swine and turtle. Fish is cheap; milk is dear ($1\frac{1}{2}$ anna per 2 lbs.). Meat costs from $1\frac{1}{2}$ to 3 annas per 2 lbs. Fruits are largely eaten at each meal; they are cheap, and for the most part nutritious and digestible; twenty-nine kinds are named. The dietary in the jail varies with duration of imprisonment (one, two, or three months) and labour. (Diets Nos. 5, 6, and 7.)

5. Dr. E. J. GAYER, of Burrisaul, states that the industrial classes eat two meals daily, costing 6 pice each, and each consists of rice 1 lb., fish 6 ozs., dal 4 ozs., and vegetables 6 ozs. The food is prepared only from the best rice (the cheaper kinds being eaten by those who can only afford 4 to 5 pice a day), and is made into curry. The foods are all wholesome. The jail dietary is very poor—only about half of the dietary in freedom. It is monotonous and injurious to health. The weight of the prisoners in $\frac{163}{273}$ cases lessened, and on the whole 273 the average loss was 9 ozs. The rice is boiled separately, and the fish, dal, &c. made into curry, as in freedom. The kind of food varies somewhat with each month. There is no variation in food with duration of imprisonment, and on Sunday it is in all cases that of the non-labouring class.

6. Dr. J. H. THORNTON, jail at Cherra Poonjee, states that the better class live upon rice and fish, the latter fresh (yet decomposed) in the cold season and dried in the sun in the rainy season. They also eat boiled vegetables, opium, bhang, &c., drink strong spirits, and smoke tobacco. Afterwards they eat meat. The poorer Hill-class find rice too expensive, and live upon potatoes and other vegetables. In the interior they eat millet, maize, &c. Where very poor, they live chiefly upon roots. The diet and habits are most injurious to health. The mortality is very great, and fevers, bowel-complaints, rheumatism, &c., prevail. The jail dietary is varied only with the labour. (Diet No. 3.)

7. Dr. J. G. FRENCH, of Assam, gives an account of the various kinds of rice, and of its harvesting and cooking. The poorer class eat from $1\frac{1}{3}$ to 2 lbs. daily, but the wealthier persons eat only from 10 to 16 ozs., and obtain other foods not procurable by the poor. Dal is eaten by the higher classes to the extent of 2 to 3 ozs. daily, whilst the poor do not obtain it, or get only the coarser kinds. Some kinds are unwholesome, and produce bowel-complaints. Fish is very plentiful, except in the heavy rains; and the small ones, in a state of decomposition, are eaten by the poor. The daily quantity is about 4 ozs. for the poor and 6 ozs. for the higher classes. Milk is not much used, except by the better classes. Mustard-oil is eaten to the extent of $\frac{1}{2}$ oz. by the poor, and 1 oz. by the rich, or the latter obtain ghee. Meat is not eaten by Hindoos. Salt to the extent of $\frac{1}{8}$ to 1 oz. is eaten daily, or in its absence the ashes of the plantain. Vegetables and fruits are used largely, and a long list of them is given, under the heads of, first, leaves and stems; second, roots and fruits; and third, acid or seasoning articles; and about 8 ozs. of them a day is eaten.

Mussulmen eat the same food as the Hindoos, and in addition eat the flesh of goats, kids, cows, buffaloes, &c.; but there are not many Mussulmen there. Hill-men take food similar to that of the Mussulmen; and in addition eat pigs', pups', and leopards' flesh. They also drink much *moad*, an intoxicating drink obtained from rice. The following is the scheme of quantity, and cost of food.

Poorest Class—Hindoo Labourers.			Better Class.	
	Quantity.	Cost.	Quantity.	Cost.
	ch. k.	a. p.	ch. k.	p.
Rice	12 0	$1\frac{1}{2}$	10 0	$1\frac{1}{4}$
Vegetables	4 0	$\frac{1}{2}$	3 0	$\frac{1}{2}$
Fish	2 0	$\frac{1}{2}$	2 0	$\frac{1}{2}$
Dal	1 0	1	1 2	$\frac{1}{2}$
Mustard-oil (not often used)	0 1	$\frac{1}{4}$	0 1	$\frac{1}{4}$
Salt	0 1	$\frac{1}{8}$	0 2	$\frac{1}{4}$
Massalahs	....	..	0 1	$\frac{1}{4}$
Ghee	....	..	0 $\frac{1}{2}$	$\frac{1}{4}$
	19 0 or 39 ozs.	1 0	17 $2\frac{1}{2}$ or $35\frac{1}{4}$ ozs.	$3\frac{3}{4}$

The Assamese are stronger than other Hindoos; but the Hill-men and Mussulmen eating flesh are superior in muscular development, activity, strength, and courage. Opium-eating prevails, and renders the victims susceptible to attacks of epidemics and malaria. Rice and curries compose the meals. He thinks the new jail dietary sufficient, viz. 28 ozs. for non-labouring, and 24 ozs. for labouring prisoners; and approves the plan of putting all prisoners on the first to begin with, until accustomed to the regular dietary of the jail and in full work. He gives the present scale of diet, which varies with the race and labour. (Diets Nos. 1 and 3.)

8. Dr. W. B. Beatson, of Chittagong, states that rice to the extent of about 27 ozs. is the daily food. New rice is generally eaten, and is cheaper than old, but not so nutritious. It is said to be productive of rheumatism, perhaps from the formation of excess of lactic acid. The rice-water is not always thrown away. Labourers take an early breakfast of the rice left from yesterday, and two other meals of rice and vegetables. Chillies are eaten so largely as 3 lbs. per month. Oil or ghee and dals are too expensive, and therefore but little eaten. The skins of seeds are rejected as indigestible, and some of the dals are unwholesome. Vegetables are eaten abundantly, and cooked with condiments, fish, and shrimps. A loathsome compound for human food is made from the refuse of fish dried in the sun, and mixed with the excrements of the crows feeding upon it. The Mussulmen eat animal food in considerable quantity when they can afford it. A boat's crew of twelve men ate the fore quarter of a large hog-deer, with oil and rice, at one meal; and would eat at a meal 10 lbs. of pumpkin, 18 lbs. of rice, 8 ozs. of shrimps, 2 ozs. of chillies, 4 ozs. of salt, with sometimes 2 lbs. of dal cooked with salt and chillies. Milk is highly appreciated, and particularly by the Hindoos. The Feringhees eat more largely of poultry, pork, and other animal foods. The Mughs are almost carnivorous, eating snakes, lizards, &c. Spirits and intoxicating drugs are largely taken. The Mughs in the hilly districts are the finest race of men, and then the Hindoos of the fishermen caste. The Feringhees are a weak and degenerate class, and as a race the Mussulman and Hindoo natives are anything but robust. Hygienic conditions are very defective, and miasma is rife. The new jail system of dietary had been too recently introduced to enable him to show the effect of

it, but he thinks it will improve the condition of the prisoners. The former scale was also sufficient.

9. Dr. B. Bose, of Furreedpore, enters largely into the general value and influence of vegetable and animal aliments. Among the amylaceous aliments he includes rice, wheat, barley, sweet and common potatoes, yams, maize, ole, and green plantains. Rice is the national Bengalee food, and the others are only supplements. The daily quantity is 26 ozs. among the labourers, and 20 to 22 ozs. among the higher classes. Various modes of cooking it are given. Fish, flesh, dals, vegetables, and condiments are eaten as largely as the means will allow; but they never supplant rice. Leguminous seeds are treated as under the head of amylo-albuminous aliments, and Dr. F. Watson's analyses are quoted. The daily consumption is 3 ozs. Of oleaginous aliments, mustard-oil is particularly referred to, and its external use in rendering the skin soft, in protecting it from heat, in restraining evaporation*, and in various other ways, is pointed out. The cocoa-nut, both in its fluid and kernel, is treated of. About 1 oz. of oil is eaten daily. Sugars are eaten to the extent of about 2 ozs. a day, and are made into sweetmeats or festive aliments. The sweet fruits and other sources of sugar are largely considered. Mucilaginous substances are eaten to the extent of 4 ozs. daily; also acidulous and bitter foods and condiments in an unascertained quantity. Fish is a most important part of the diet, and is almost the only source of animal aliment. Milk is used not uncommonly. Butter is used only on special occasions. Ghee is simply butter melted by heat, and will keep good for many months; it is less digestible than butter. Skimmed milk and buttermilk are eaten, and he describes various preparations of milk. Flesh, being dear, is seldom used by the working classes, whether Hindoos or Mahomedans: the latter consume fowls, beef, and mutton. Eggs are rarely eaten, but are sold. Hindoos eat he-goats, kids, turtles, pigeons, and ducks, and their eggs; but the kids must be sacrificed to their gods. *Palaows*, *kaleeas*, *kormas*, *koptas*, and *katee-kababs* are the most common dishes, and their preparation is described. The daily consumption of animal food, including fish, milk, and flesh, is 7 ozs. The jail dietary is varied with labour and duration of imprisonment, and is described. (Diets Nos. 5, 6, 7, and 8.)

10. R. Brown, Esq., of Sylhet, states that flesh is eaten very sparingly. Fowls are eaten occasionally. Fish is plentiful, and is a most important and staple animal food. The kinds of fish and the modes of cooking are described. Rice, from its cheapness, constitutes a large part of the dietary, and next in importance is dal. He names the vegetables and fruits in use. Milk, ghee, &c. are very little used except by the ryots, who keep cows, and they use them in considerable quantities. A quarter-ounce of ghee is used to a half-pound of dal. Sweetmeats are eaten very sparingly by the poor. Spices and onions are used largely. Opium-eating prevails among Mussulmen and Hindoos, and drinking of spirits by those living in the hills. There are usually three meals daily, the chief of which is that at midday. The following are the quantities (see Table, p. 182).

In some places fish is almost the only article of diet. The jail dietary varies with race and labour, and is given. (Diets Nos. 1, 2, 3, and 4.)

Barrackpore.

11. Dr. R. Fryer, Bancoorah, divides the inhabitants into two classes, of

* As shown in my work, 'Health and Disease as influenced by the cyclical Changes in the Human System.' London, 1860.

	Morning.	Midday.	Evening.
	oz.	oz.	oz.
Rice	8	14	12
Fish or curry	4	..	..
Salt	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$
Dal	..	2	..
Fish or dal	..	..	3
Fish	..	4	..
Vegetables	..	2	2
Oil	..	$\frac{1}{4}$	$\frac{1}{4}$
Ghee	..	$\frac{1}{8}$	$\frac{1}{4}$
Massalahs	..	1	..
Buttermilk	..	4	..
Milk	..	..	4
Amlee	..	..	$\frac{1}{4}$
	$12\frac{1}{8}$	$27\frac{5}{8}$	22 $=$ 3 lbs. $13\frac{1}{4}$ oz.

whom the *Chasa*, *Salee*, *Khoibut*, *Sorak*, *Sooree*, and *Agoree* castes are in tolerably good circumstances. They eat thrice a day. The morning meal consists of somewhat less than 2 ozs. of rice, which they eat parched. The midday meal consists of rice 1 lb., vegetables 2 ozs., dal 1 oz., salt $\frac{1}{2}$ tolah, and oil 1 tolah. The evening meal is composed of rice 8 ozs., vegetables 1 oz., dal 1 oz., salt $\frac{1}{2}$ tolah, and oil 1 tolah. A quarter of a pice worth of *massalah* is eaten with the midday and evening meal. The second class, consisting of the *Khoira*, *Lohar*, *Bagdee*, *Majee*, *Baoree*, *Santhal*, *Koorme*, *Bhoomig*, *Bhooea*, *Mall*, and *Khariah* castes, are in inferior circumstances, and live chiefly upon animal food. They rarely eat much rice, and only during six or seven months of the year. During the remainder of the year they live upon jungle-leaves, fruits, and seeds, with almost all kinds of jungle animals and fowls. The jail dietary varies with labour, the Sunday's food containing 2 ozs. of rice and 2 ozs. vegetables less than that of the other days, and the non-labouring classes have the Sunday's food daily. The food of the labouring prisoners on six days of the week contains $3\frac{1}{2}$ ozs. more food than that of the free population, and upon it the prisoners keep up their health and weight. (Diet No. 9, nearly the same as No. 4.)

12. Baboo K. C. Chatterjee, Baraset, states that the ordinary food of the labouring population consists of rice (both varieties, *aoos* and *amun*), fish, vegetables, dal, oil, salt, condiments, and occasionally acidulous fruits, milk, curd, whey, and flesh. The vegetables are of the indigenous and cheap kinds; the fish fresh, dry, and salted. Dals are eaten once or twice a week. The Hindoos eat only the he-goat among animal foods, and then only on festive occasions; whilst the Mahomedans eat goat, sheep, fowl, &c., and eggs; but, though not prohibited by their religion, they seldom eat beef. The *Kaorahs* and *Domes* eat pigs, and the *Moochees* the flesh of buffaloes and dead cows. Mustard-oil, turmeric, sea-salt, chillies, black pepper, and mustard-paste are eaten by all classes, but onions and garlic by the Mahomedans and lower orders of Hindoos only. The farmers occasionally eat milk, curd and whey, and molasses is largely eaten by both Hindoos and Mahomedans. The jail dietary differs from the free dietary only in the absence of milk;

and the following Table shows the weekly quantity and kind of food, varying with duration of imprisonment, and compared with the free dietary.

	Free Labourers.				Prisoners.							
	Hindoos.		Mahomedans.		Above 3 months.		From 2 to 3 months.		From 1 to 2 months.		Within 1 month.	
	s.	ch.	s.	ch.	s.	ch.	s.	ch.	s.	ch.	s.	ch.
Rice	6	8	7	0	4	5	4	1	4	1	3	14
Dal	0	4	0	3	0	15	0	8	0	8	0	5
Vegetables	2	0	2	0	1	4	0	8	0	4	0	1
Fish	0	2	0	2	0	6	0	0	0	0	0	0
Flesh	0	0	0	3	0	6	0	0	0	0	0	0
Salt	0	3	0	3	0	$2\frac{1}{2}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$	0	$1\frac{3}{4}$
Oil	0	2	0	2	0	$2\frac{1}{2}$	0	1	0	$\frac{1}{4}$	0	$\frac{1}{4}$
Massalahs	0	1	0	1	0	$2\frac{1}{2}$	0	0	0	0	0	$\frac{1}{4}$
Onions and garlic	0	1	0	4	0	$2\frac{1}{2}$	0	$\frac{1}{4}$	0	$\frac{1}{4}$	0	$\frac{1}{4}$
Whey	0	8	0	0	0	0	0	0	0	0	0	0
Jagree	0	2	0	2	0	0	0	0	0	0	0	0

The rice used is the coarse kind only. The varieties of dal are limited. Goat's flesh is given when fish is scarce. Two meals daily are given, at 11 A.M. and after 5 P.M. Mahomedans are stronger and healthier than Hindoos because of intermixture of races and more nutritious food. The locality is low and marshy, and induces endemic diseases. The prisoners suffer from bowel-complaints, mental despondency, &c.; and, from confinement, the digestive powers cease in a few months to take or digest the allowed quantity of food.

13. Dr. A. J. Sheridan, of Beerbhoom, gives a detailed account of the foods, and their preparation, in use there; and, after stating that it is difficult to get reliable information, shows that at the two meals daily the following food is eaten:—rice 24 ozs., dal 3 ozs., parched rice (moorhee) 4 ozs., vegetables 6 ozs., oil 1 oz., massalah 1 oz., salt 1 oz. = 40 ozs. daily. Sometimes 3 or 4 ozs. of fish is substituted for the dal and vegetables; and when more food is required, the dearer kinds are omitted, and the cheaper increased. The poor food renders them liable to endemic, sporadic, and epidemic diseases. The jail dietary varies with the labour, and on Sundays it is that of the non-labouring classes. He deprecates the cooping-up of the prisoners by high double and triple walls, and the deficient supply of fresh air. (Diet No. 1.)

14. Dr. A. A. Mantell, of Balasore, describes in detail the several foods in use, as well as their modes of preparation, and includes spirits and intoxicating drugs. The inhabitants not addicted to the latter enjoy good health; but the smallness of the quantity of protein-compounds prevents a high state of vigour among the Hindoos. The sedentary become fat. Fever and bowel-complaints prevail. The long intervals between meals predispose to endemic disease. The jail dietary varies with labour and duration of imprisonment, and is sufficient for health. The mortality has doubled since 1859, and is due to the confinement of the prisoners within the walls instead of being employed on the roads. (Diets Nos. 5, 6, 7, and 8.)

15. Dr. H. J. Williams, Burdwan, after describing the foods under the heads of rice (two kinds, *hona* and *rokum*), dal (seven kinds), fish, flesh (very rarely eaten), milk (eaten by all classes), vegetables (twenty kinds), acid

fruits (six kinds), ripe fruits (thirteen kinds), with sweetmeats, *pawn*, and tobacco, states that the average health is good, and the people are well nourished. The jail dietary varies with labour and duration of imprisonment. The sameness of food and the small quantity of animal food and phosphates lead to phthisis, and the lowest and poorest classes think life scarcely worth possessing in the absence of pawn and tobacco. (Diets Nos. 5, 6, 7, and 10.)

16. Dr. R. PRINGLE, Cuttack, states that among the coolies and the lowest class, rice, with watercresses and the small crabs found in tanks and jheels, is almost the sole food. The quantity of rice is $\frac{3}{4}$ seer (= 79 tolahs), two-thirds eaten at the morning and one-third at the evening meal. The natives generally add 1 chit. of dal and perhaps 2 chit. of vegetables to the evening meal. When wood is dear, the evening meal is the only hot one. The natives are almost exclusively Hindoos, and eat very little animal food. On the sea-coast fish constitutes half the diet, whilst inland they consume an increased quantity of vegetables, rice, and dal; and in the independent States, at a distance from rivers and cultivation, rice is almost the sole food. The inhabitants of the coast are in the best health. Only the lowest class of Hindoos take opium and spirits. Mussulmen are well fed, since, in addition to the food of the Hindoo, they take from 2 to 3 chit. of flesh daily. The jail dietary varies with labour and duration of sentence, and is the best on Sundays. The diet is sufficient. (Diets Nos. 5, 6, and 7.)

17. H. COLLINS, Esq., Darjeelung, states that in the hills there are four distinct races, viz., *Lepchas* (natives of Sikkim), *Bootias* (natives of Bootan), *Nepaulese*, and *Plains-men* of all castes. The Lepchas, Bootias, and Nepaulese eat twice in the day, the two former 11 ozs., the last 12 ozs. to 16 ozs. of rice; the two former 8 ozs. of meat, chiefly pork, with a small quantity of salt, 2 to 4 ozs. of vegetables, and $1\frac{1}{2}$ pint of a fermented liquor (*murrua*), whilst the latter, in addition to the rice, take 6 ozs. to 8 ozs. of dal and a small quantity of salt and vegetables, chiefly potatoes. The last also sometimes eat goat's meat, mutton, pigeons and fowls, and bread made of wheat, millet, or Indian corn. The two former take tea instead of *murrua* in the morning, if they can afford it. The higher castes of Nepaulese do not eat meat after their marriage, and never drink fermented liquors; whilst the lower castes indulge in both, when they can procure them. The Lepchas and Bootias, and particularly the former, are remarkably healthy, and have well-developed leg-muscles, but have not great powers of endurance. The Nepaulese are short, active, and wiry, with little muscular development, but great powers of endurance. They are moderately healthy, but liable to disease of the lungs and bowels, the latter due to the farinaceous food, and the former to insufficient clothing. The Lepchas and Bootias wear woollen clothing. The jail dietary varies with labour, duration of sentence, and day of the week, and is insufficient to maintain health and weight, especially for the Lepchas and Bootias. (Diets Nos. 5 and 11.)

18. Dr. S. C. AMESBURY, Dinagepore, states that rice, vegetables, fruit, massalahs, fish rarely, and meat occasionally, constitute the dietary. The daily quantity is, rice 24 ozs., and vegetables, including dal $\frac{1}{2}$ a pice worth. There are three meals a day, the first consisting of the food left from the former meal. The respectable classes, with food of good quality and well cooked, are in good health, whilst the poorer, having the opposite conditions, are liable to scurvy, diarrhœa, and general debility. The jail dietary is sufficient, as the prisoners gain weight. He agrees with Dr. Mouat that fresh vegetables are better food than dal. The dietary varies with labour, and

somewhat with the day of the week, and on Sundays it is that of the non-labouring class. (Diet No. 4.)

19. Dr. J. Elliot, Hooghly, states that the dietary of the free labourer is much larger than that of prisoners, and that the occupation of the former in the open air improves the appetite and digestion. The dietary in jails varies with labour, and somewhat with the day of the week, and on Sundays is that of the non-labouring prisoners. The prisoners are as healthy as the same class when free. He gives two tables showing the dietary in various classes or castes of the people, with their occupations, and the kind, quantity, and price of foods. Cowherds and milk-sellers eat $2\frac{1}{2}$ lbs. of rice, $\frac{1}{2}$ lb. of dal, and 1 lb. of milk, costing six pice, whilst numerous others supplant the milk by 2 ozs. of fish or the flesh of dead cattle or other meat, the daily cost varying from four to six pice. The Hindoo labourer takes no animal food but fish, whilst the Mahomedan always eats meat. (Diet No. 11.)

20. Baboo H. Mookerjee, Ooterparrah Dispensary, states that the food consists of cereals, as rice, grain, &c., eaten with milk, rancid butter, fish, mustard- and linseed-oil, vegetables and leaves; roots and tubers, as potatoes, carrots, onions, turnips, radishes, &c.; fruits, as plantains, water-melons, mangoes, tamarinds, &c.; peas, beans, and other varieties of pulse; molasses and sugar. The effect of the dietary is salutary.

21. Dr. T. W. R. Amesbury, Jessore, states that at two meals daily some or all the following are eaten:—rice 24 ozs., dal 8 ozs., vegetables 8 ozs., fish 12 ozs., oil 12 ozs. (?), salt $\frac{1}{2}$ oz., spices $\frac{1}{2}$ oz., milk 2 lbs., ghee 6 oz., and to these the Mahomedans add flesh. They regard quantity rather than quality, and consider the quantity of rice as the measure of the meal. Vegetable food is more adapted to the climate than animal food, and the latter of inferior kind is the cause of skin-disease among the Mahomedans. Ghee is less eaten than oil by the well-to-do people, and too much of it leads to hepatic disease. The Hindoos take only milk and fish among animal foods. All classes, except strict religionists, eat intoxicating drugs. Those who live without the latter and on vegetable food thrive well, but cannot resist disease. The jail dietary varies with race, labour, and day of the week, that of Sunday being that of the non-labouring class. (Diets Nos. 1 and 2.)

22. Dr. R. F. Thompson, Maldah, states that wheat and rice are eaten in equal proportion by the descendants of the Hindostanee stock, but rice only by the pure Bengalee. Barley-meal or parched barley is much relished when seasoned with milk and sugar. Barley bread and wheaten bread and confectionary are used. Dal, fish (which is cheap and abundant), meat (not in general use), milk, and dhoe (used universally), ghee (a great favourite), mustard-oil, vegetables, particularly the potato, salt, mangoes, and river water constitute the dietary. The jail dietary varies with labour. Thus, with labour, the oldest rice 20 ozs., dal 4 ozs., vegetables 4 ozs. (fish 4 ozs., in lieu of vegetables, twice a week), salt, chillies, and oil $\frac{1}{4}$ oz. The diet of the free labourer is, the cheapest rice 20 ozs., dal, fish, or vegetables 4 to 6 ozs., or perhaps only dhoe. The jail dietary is as good as the free dietary, and the health of the convicts is good.

23. W. J. Ellis, Esq., Manubhoom, states that the working-classes are mostly low-caste Hindoos, as the *Bowrees*; yet they will eat almost all kinds of flesh, as that of tigers, rats, serpents, and even the cow. The principal diet is rice and Indian corn, on which they live entirely for six months of the year. Vegetables of even inferior kinds, and fish, which is scarce, constitute the food. Those who work in the *Mofussil* live on gruel made with rice steeped in much water, with or without vegetables boiled with salt.

They do not eat dal or curry, and the oil is used only for anointing their bodies. The town labourers take three meals daily, the first consisting of the remnants of the last evening's meal, and all classes take the rice-gruel with their other food. Such labourers earn from six to twelve pice a day; but where only three or four pice are obtained, the midday meal is dispensed with. The Indian corn is parched or ground into meal, and eaten with water. The lower classes are dissolute and drunken. The jail dietary is ample, and the labour exacted is small. Compared with free labour, it is as follows:—Convicts, rice 24 ozs., dal 6 ozs., vegetables 4 ozs., salt 1 oz., oil 1 oz., massalah 1 oz.; whilst the free labourer has 4 ozs. of dal and 1 oz. of massalah, and 2 ozs. of fish alternating with the dal. (Diet No. 12.)

24. Dr. B. Kendall, Midnapore, gives the daily free dietary as follows:—rice 24 ozs. to 28 ozs., vegetables 4 ozs. to 6 ozs., dal 2 ozs. to 4 ozs. once or twice a week, and fish when they catch any. Besides these two meals, parched rice and molasses or sweetmeats are eaten once a day. Most of the farm-labourers have cows or goats, and take milk and ghee in small quantities, whilst in towns they buy a little duhee and buttermilk. The Mussulmen also eat flesh, but irregularly. The *Sonthals* and *Dhanghurs* eat rats, squirrels, and some species of snakes. *Bowrees* eat cats and decomposing animals which have died in any way. The *Swalghur* or *Kucher* caste eat jackals, crows, and carrion. The jail dietary of 1858 (diet No. 13 appended) was deficient in fresh vegetables, and caused much sickness and mortality; and that of 1862 is insufficient in rice. The dietary varies with the race, labour, and day of the week, that of Sunday being the non-labouring scale. (Diets Nos. 1, 2, 3, and 4.)

25. J. H. Guise, Esq., Moorshedabad, states that the free dietary is as follows:—coarse rice 24 ozs. to 32 ozs., dal 4 ozs., vegetables 2 ozs. to 4 ozs., and fish 2 ozs., besides condiments; and with 4 ozs. of onions for the Mahomedans. In the eastern districts *attah* is used with rice. There is the morning meal of 4 ozs. of rice, and the two regular meals at one to two P.M. and eight to nine P.M. They smoke tobacco before and after eating. They are undersized and unhealthy. Many suffer from disease of the spleen and diarrhœa, due probably to the ill-ventilated huts and badly located dwellings. The jail dietary is sufficient; for although less than the free dietary, the prisoners generally gain in weight. It varies with duration of sentence, and on Sundays the short-term prisoners have more food. (Diet No. 8.)

26. Dr. J. J. Durant, Pooree, states that rice is the staple food, then vegetables, and then dal. Animal food, except fish, is too expensive. They are indolent and unenterprising people, living in low, dirty places, and covering their skins with turmeric paste as a safeguard against the bad effects of the sea air, which causes it to be of a yellow or jaundiced colour. All ages and sexes smoke, and drink narcotics. A detailed account of the various foods is given; and the daily dietary consists of from 16 to 18 chit.* of rice, or even double that quantity, at three or four meals, vegetables 1 to 2 chits., dal or fish 1 to 4 chits. once or twice a week, parched grain 2 to 4 chits. about noon, and salt and massalahs $\frac{1}{2}$ chit. This is sufficient in variety and quantity for an inactive people in an equable climate. They are very weak and anæmic, and should live better, particularly on animal food, and reside in more healthy localities. The jail dietary is insufficient in quantity, if not in nutriment, and leads to bowel-complaints. The allowance for the labouring convicts is, rice 12 chits., dal 3 chits., salt $\frac{1}{4}$ chit., oil $\frac{1}{4}$ chit., massalahs $\frac{1}{4}$ chit., vegetables 2 chits., fish 2 chits. $= 19\frac{3}{4}$ chits. (Diet No. 9.)

* This is the Cuttack seer $= 22\frac{1}{2}$ chittaks.

27. S. M. Shircore, Esq., Rajshahye, states that 2 lbs. of rice, 4 ozs. of dal, 4 ozs. to 6 ozs. of vegetables, 10 ozs. of fish, $1\frac{1}{2}$ oz. of oil, $1\frac{1}{2}$ oz. of massalahs, 2 ozs. of milk, 8 ozs. of dhoi, and 8 ozs. of julpaun constitute the daily dietary of the labouring classes. The dal and dhoi are, however, obtained only ten or twelve times a month, and the milk only occasionally. Julpaun consists of parched rice, peas, and grain, with salt, and is taken as the early morning meal. The class are, on the whole, pretty healthy; but they suffer from ague, enlarged spleen, dyspepsia, and bowel-diseases. The jail dietary now varies with labour and the day of the week, that of Sunday being of the non-labouring class. (Diets Nos. 9, 1, and 14.)

28. Dr. E. J. Roberts, Rajmahal, states that rice is the staple food, and the leguminous dals next. Vegetables are invariably eaten; fish is plentiful; and kids and pork are eaten by certain castes. Cakes are made from barley, oats, maize, or dals in a powdered state, and, with cold water, salt, and chilli, are eaten uncooked. Dry parched grain is eaten without further cooking. *Daugahs* eat flesh, including rats; and the *Sonthals* and *Pahareas* eat almost any kind of flesh, as that of buffaloes, bullocks, deer, pigs, rats, snakes, tigers, leopards, game, and birds of all kinds. The poorest eat $1\frac{1}{2}$ lb. of rice, and 6 to 8 chits. of vegetables, with salt and condiments, or substitute wild herbs for vegetables. Few can afford dal or fish. This costs 9 pice to 1 anna; but when $1\frac{1}{2}$ to 4 annas can be spent, dal and fish or flesh are added, and then the rice may be reduced to 10 chits. Some low-caste Hindoos eat pigs. The new jail dietary varies with labour and day of the week, the latter substituting 4 ozs. of vegetables for 4 ozs. of fish on certain days. (Diet No. 8, B.)

29. G. K. Poole, Esq., Rungpore, states the free daily dietary as follows:—coarse rice 20 ozs., dal 2 ozs., vegetables 8 ozs., mustard-oil, salt, and massalahs $\frac{1}{2}$ oz. each. Old rice is dearer, and is preferred. Rice under six months old is unwholesome. The mustard-oil is the only fat used, and when used in large quantities causes irritation of the bowels. Fish and meat are taken once in ten or fifteen days, and are not cheap or abundant. Milk and duhee are used occasionally. Bread or attah is not used. Tobacco is smoked. Betel-nuts are chewed, and as an astringent promote digestion. The diet, when the food is good, keeps them in health. The former jail dietary was insufficient, and the present one varies with labour and day of the week. (Diet No. 11.)

30. Dr. A. V. Best, Raneegunge, states that the people work in the coal-mines or on the land. Animal food of all kinds is eaten largely by the mining and jungle castes, except by the Brahmins. Fish, especially small shrimps, is a favourite article of food. Ghee and duhee from buffalo-milk are eaten by the better classes, and mustard-oil by the poorer; but some do not obtain any. Rice is the staple food, and dals are largely used. Maize is eaten, and attah is too expensive. Fruits, roots, leaves, fungi, and a common spirit are used. The prisoners are allowed three pice per day, and live as at home. They do not suffer in health.

31. A. J. Meyer, Chyebarra, states that it is a hilly district, and the coolies, being mountaineers, differ in their dietary from the other classes. In their jungles they eat rice and vegetables, and the flesh of all animals, birds, and ants, even if dead, and drink much strong drink. The latter in certain forms fortifies the constitution against disease. One meal a day, with the spirits (hurreah), suffices, and keeps them in excellent health. It consists of 1 lb. of rice, with dal or vegetables, seasoned with salt and chilli, but without fat, oil, onions, or garlic. Meat is rarely eaten. The other races eat two or three meals

daily, including 1 lb. or $1\frac{1}{4}$ lb. of rice, with vegetables, milk, or dal. A list of the different vegetables which are used is given. The jail dietary varies with labour, duration of sentence, and day of the week. That for short sentences is abundant; but long-sentenced prisoners lose weight, and nine out of twelve (Coolie or Sonthal) fall victims to the diseases of prisons. (Diets Nos. 11, 5, 6, and 7.)

32. Dr. N. Jackson, Sumbulpore, states that twelve chittaks of rice are eaten daily. Wheat is eaten occasionally; dal, vegetable, and fish universally. Maize, three or four chits., occasionally. Meat, six or eight chits., once a week by the well-to-do classes. Milk, 1 lb. daily by the higher, and every four or five days by the lower class. Cheese, oil, ghee ($\frac{2}{3}$ oz.) by the better classes, 'til' oil by the lower. Sugar or molasses 1 to 4 ozs. when chapattees are eaten. Massalahs from $\frac{1}{2}$ to 1 oz. daily. Spirits are in general use. The total weight of food daily is 3 lbs. The jail diet is too same and uniform, and there is no surer way of extinguishing an unhealthy man than by lengthened confinement in jail.

33. Dr. G. M. Govan, Ranchee, states that tribes and sects differ much in dietary, and he describes them. The coolies work hard, and (a man, or a man and his wife?) eat, thirteen out of fourteen days, 8 lbs. of rice, 8 ozs. of vegetable, and $\frac{1}{2}$ oz. of salt daily; on the remaining day they eat 6 lbs. of rice, 4 ozs. of dal, 1 oz. of vegetable oil, and 2 lbs. of flesh at two meals (midday and 6 P.M.) daily. They drink fermented beer and spirits. They are very healthy. The jail dietary is a good one, and consists of coarse rice 24 ozs., dal 6 ozs., vegetables 4 ozs., salt and seasoning $\frac{1}{2}$ oz., and 4 ozs. of flesh once a week for such as choose to have it.

34. Dr. W. W. Hende, Nagpore, shows that the dietary differs with caste, and gives the following as the daily food, in ounces, taken at two meals:—

	Attah.	Rice.	Dal.	Jowaree.	Barai or grain-flour.	Ghee.	Oil.	Milk.	Curd.	Meat.	Vegetables	Curry-stuffs.	Salt, in drachms.
Brahmins	16	16	4	...	2	1	1	32	8	...	8	1	6
Hindoos	24	8	4	...	...	1	$\frac{1}{4}$	16	8	6	8	$1\frac{1}{2}$	4
Mahomedans	24	8	4	...	...	1	$\frac{1}{2}$	32	...	6	8	$1\frac{1}{2}$	6
Dheers and other low-caste Hindoos	...	...	4	24	...	...	$\frac{1}{4}$	...	...	...	8	$\frac{1}{2}$	4

but all these foods are not eaten on the same day. The jail dietary varies with labour; the highest mortality with sentences of under one year. Both jail and free populations suffer from fever and bowel-complaints. (Diet No. 15.)

35. Dr. W. R. Grylls, Chindwarrah, states that the *Gonds proper* and *Koorkoos* eat daily 2 lbs. of coarse wheat-flour, unleavened, 4 or 5 ozs. of dal, one or two chillies, salt, vegetables, and condiments. They are fond of any kind of flesh, and drink intoxicating fluids. The *Goojurs* eat only vegetable food, and do not drink spirits. The *Megrahs* are apathetic, and will eat and drink anything. All eat vegetable oil; but ghee is too dear. Rice is almost unknown. The jail dietary varies with labour and sex, and rice is substituted for wheat-flour twice a week. (Diet No. 16, and in another Report, No. 15.)

36. Dr. S. J. Wyndowe, Bhundarrah, states that the Mahomedans eat 16 ozs. of rice, 16 ozs. of attah, 4 ozs. of meat, 8 ozs. of vegetables, and $\frac{1}{2}$ oz. of curry-stuff daily; the Brahmins the same quantity of rice, attah, vegetables, and curry-stuff, with 6 ozs. of dal, 8 ozs. of milk, and 2 ozs. of ghee; the Hindoos 8 ozs. of rice, 16 ozs. of attah, 4 ozs. of dal, 4 ozs. of vegetables, 2 ozs. of ghee,

and $\frac{1}{2}$ oz. of curry-stuff; whilst the low castes, Dheers, &c. eat 4 ozs. of dal, 16 ozs. of jowaree, 4 ozs. of vegetables, $\frac{1}{2}$ oz. of curry-stuff, 4 ozs. of fish, and 1 oz. of oil. The jail dietary varies with labour and day of the week. The food is cooked for the midday meal, and is eaten cold at the five P.M. meal. The people are spare and weakly, and stomach and bowel diseases with fever are common. (Diet No. 15.)

37. Dr. C. E. W. Bensley, Raepore, states that both rice and wheat are largely grown there, and the latter sometimes supplements the former. He gives two scales of free dietary, one containing rice 24 to 32 ozs., attah 6 to 8 ozs., dal or vegetables 6 to 8 ozs.; fish or meat once a fortnight, in lieu of dal and vegetable, 8 ozs.; milk, dhye, or buttermilk 12 to 16 ozs., with a little ghee or oil and condiments. The other contains the same quantity of rice, dal, and vegetables, with buttermilk every three or four days 16 ozs. Fish or meat only once a month, and milk or dhye once in two or three weeks. The labouring classes are agriculturists and possess cows. Those living on the second scale are not so strong as the others. The whole district is miasmatic. Dyspepsia prevails among all classes. The jail dietary varies with labour. The improved dietary had been beneficial. (Diet No. 17.)

38. J. H. Carr, Esq., Belaspore, states the kind of foods used, and the quantity eaten at a time, but does not give a complete daily dietary for any class. The jail dietary consists of $18\frac{1}{10}$ ozs. of wheat-flour (or 15 ozs. of rice), $3\frac{1}{2}$ ozs. of dal, or $7\frac{1}{2}$ ozs. of green vegetable, with a little salt, oil, and condiments.

39. T. King, Esq., Kowtah, states that the dietary of the industrial population is as follows:—attah or wheat, with the bran partly removed, 24 to 32 ozs., rice 16 to 24 ozs., dal 2 to 4 ozs., Indian corn, roasted between meals, 2 to 4 heads, and gram 2 to 4 ozs. The labouring classes eat 24 to 40 ozs. of jowaree (a species of imphey-seed), 2 to 4 ozs. of dal (lauk), and 4 to 6 heads of Indian corn. The jail dietary varies with labour and day of the week. (Diet No. 18.)

Dinapore.

40. Dr. J. B. Allen, Behar, gives a list of the various kinds of foods and tobaccos in use, and the following is the quantity of the former which is eaten by the free labouring classes at one meal, but he does not state whether more than one meal is eaten daily, viz.:—rice 8 chits.* or flour 12 chits., dal 2 chits., vegetables 3 chits., mustard-oil and spices $\frac{1}{2}$ chit. each, salt $\frac{1}{4}$ chit., and occasionally 8 chits. of meat. The jail dietary is less than the home dietary, and the prisoners are dejected and depressed from confinement and absence of tobacco, yet they increase in weight. It consists of rice 24 ozs., or an equivalent in flour, dal 6 ozs., vegetables 4 ozs., ghee, salt, and massalahs $\frac{1}{2}$ oz. each. (Diet No. 13.)

41. Dr. T. B. Farncombe, Bhangulpore, states that the food, except rice, of the agricultural classes varies much with the season and locality. The jail dietary varies with labour and length of sentence. (Diets Nos. 11, 5, 6, and 7.)

42. Dr. N. C. Macnamara, Tirhoot, divides the inhabitants into four classes, and largely describes them and their dietary. The Brahmins eat 1 to $1\frac{1}{2}$ lb. of bread, 1 to $1\frac{1}{2}$ lb. of rice, 6 ozs. of dal, with butter, vegetables, and salt, and sometimes $\frac{1}{2}$ lb. of fish or flesh daily. Some take 1 to $1\frac{1}{2}$ pint of milk once or twice a day. Gwallas and Koormees, who are shepherds, eat 1 to $1\frac{1}{2}$ lb. of

* The seer here = 2 lbs. 12 drachms when bought in quantities of 5 seers and upwards, but only = 1 lb. 13 ozs. 9 drachms at the bazaar-rate below 5 seers.

Indian corn and barley-bread, $1\frac{1}{2}$ lb. of rice, 5 ozs. of dal, 1 to 2 ozs. of butter, $\frac{1}{2}$ lb. of duhee, with vegetable and salt, and $\frac{1}{2}$ lb. of fish or flesh thrice a week. The jail dietary now varies with labour, and is also divided into classes. (Diet No. 14.)

43. Dr. J. M. Coates, Chumparum, states that about 2 lbs. of rice, 1 lb. of dal or fish, $\frac{1}{2}$ lb. of vegetables, and $\frac{1}{2}$ oz. of oil, spices, and salt each, is the ordinary free dietary; and describes the mode of cooking them. Some oils are eaten in the cold and others in the hot season, whilst but little dhoe and ghee are obtained. The jail diet varies with labour and day of the week. The Sunday's diet is that of the non-labouring class, and it suits the prisoners. [As I think it probable that there is an error in the report, in quoting ounces instead of chittaks, I do not transcribe the table.]

44. Dr. J. Sutherland, Patna, shows that the jail diet varies with labour, and describes at length the various kinds of food eaten by the population, with the cost, and with remarks added. (Diet No. 19.)

45. Dr. T. Duka, Monghyr, states that his information has been derived at second-hand. The lower classes eat three meals a day. The jail dietary varies with labour. The free dietary is not given in daily combination. (Diet No. 20.)

46. Dr. R. F. Hutchinson, Shahabad, shows that the total weight of food obtained by the free labourers varies from 18 to 24 chits. daily; but he does not state of what it is composed, and the weight of each kind. He shows the evils of the jail system, and states that scurvy and diarrhœa are the jail pests. The jail dietary varies with labour and day of the week, and perhaps with race. (Diets Nos. 11 and 2.)

47. Dr. A. G. Crewe, Purneah, states that the dietary of the free population consists of rice 20 ozs., dal 4 to 6 ozs., fish 4 to 8 ozs. sometimes, and vegetables 4 to 8 ozs.; milk and curd are much used. The new jail dietary varies with labour. (Diet No. 14.)

48. Dr. W. F. Goss, Sonthal Pergunnahs, states that the Hindoos use but little animal food, and that is fish, milk, kid, and ghee. Only the lower classes eat pigeons, mutton, water-fowl, and pork. The Sonthals eat all kinds of flesh. Vegetables, fruits, and various kinds of grain are eaten. The jail diet consists of rice 24 ozs., dal 4 ozs., salt, massalahs, and oil $\frac{1}{2}$ oz. each, daily, and sustains the health.

49. Dr. S. Delpratt, Hazareebaugh, states that the daily quantities of food obtained by the free labourers consists of 28 ozs. of various kinds of grain, dal or vegetables 12 ozs., with salt and condiments, and sometimes parched rice, gram, wheat, or Indian corn in addition. They eat three meals daily. The jail diet varies with labour, the non-labouring receiving no meat, and 2 ozs. less of rice and vegetables than the labouring. The mortality was excessive, but the health is now better. (Diet nearly like No. 11.)

50. Dr. C. J. Jackson, Sarun, states that the constant food of the free labourer is the cerealia and their allies, leguminous seeds, and condiments. The occasional additions are tubers and succulent roots, leaves, fruits, and melons. He states the chemical and botanical characters and the price of each. The jail dietary varies with labour and day of the week. (Diet No. 14.)

Benares.

51. Dr. A. H. Cheke, Benares, states that the foods in ordinary use are flour, rice, dal, curds and whey, goor or treacle-cakes, with acid mixtures, as tamarinds and other spices. The flour is prepared from wheat, barley, Indian

corn, &c., and is ground between stones. Dal is used daily, but rice is not much appreciated. The weight of food is 2 lbs. at the principal meal, but the daily quantity is not given. The jail dietary is composed of barley, ground gram, flour, rice, dal, vegetables, oil, and salt; and parched gram is given at noon, instead of prepared food. The health of the convicts is better than that of free labourers.

52. Dr. W. R. Hooper, Azimghur, states that rice is dear and but little used. Wheat is dear, but is eaten more largely than rice; whilst barley is the staple food, as rice is in Bengal. Dals, curries, molasses, fish, and fruits are extensively and largely eaten. Animal food is not obtained by the poor, but is extensively consumed by the higher classes. Beef is eaten only by Mahomedans; mutton and goat's flesh only by the better classes; whilst pigs are kept in large numbers, and eaten by the labouring classes. Arrack is consumed in very large quantities, except by high-caste Hindoos. The poor, as a rule, take only one substantial meal daily, and that in the evening; others take two meals. The daily weight of food is 2 lbs. The jail dietary varies with labour and day of the week. The prisoners enjoy very good health. (Diet No. 21.)

53. Dr. A. J. Dale, Jounpore, informs us that there is much variation in the statements of the quantities of food eaten. About $1\frac{1}{2}$ lb. ($2\frac{1}{2}$ lbs. to $2\frac{3}{4}$ lbs.) of cereals, dal, and vegetables is eaten daily, and meat, fish, and fowl occasionally. The jail dietary varies with the day of the week. (Diet No. 21, B.)

54. Dr. A. Garden, Ghazeepore, describes at great length the various articles of food, with their price, in use there. The dietary is chiefly vegetables, from want of means, or inclination, and from religious prejudices. Two classes and castes only abstain from meat entirely, viz. *Brahmins* and *Bhugguls*; but they take milk. *Mussulmen*, *Kaeths*, *Chumars*, *Domes*, and all very low-caste Hindoos eat meat whenever they can get it, whilst *Boonhars*, *Chuttrees*, and *Aggur-wallahis* eat it only occasionally. High- and middle-caste Hindoos eat only mutton and goat's flesh; whilst mutton, beef, buffalo-flesh, goat's flesh, and fowls are eaten by the Mahomedans. The quality of meat varies much; and if the animals die naturally, some eat the flesh. Milk of the cow, buffalo, and goat is the most important and largely consumed animal food by all classes. Ghee and oil are eaten largely by the well-to-do classes, but the poor obtain but little. Wheat and barley, with Indian corn, are the staple cereals; dals, gram, vegetables, and spices are eaten largely and universally; salt is eaten by all; sugar is largely eaten; pickles are luxuries; spirits are largely consumed by some, and detested by others; tobacco is much more used than bhang or opium. There are two meals daily, except by the very poor, who have one in the evening, and take *suttoo* and water and parched grain at other parts of the day. The amount is very imperfectly stated. Diseases of low type abound among the worst-fed. The jail dietary varies with labour and day of the week. (Diet No. 21.)

55. Dr. J. A. Jackson, Allahabad, gives the jail dietary, which varies with labour and day of the week. The prisoners enjoy excellent health. (Diet No. 21.)

56. T. T. Sherlock, Esq., Futtehpore, states the kinds of food in use, with the quantity of meat which is consumed by an adult prisoner, but does not give the daily dietary.

57. Dr. J. Jones, Cawnpore, states that the foods in general use are wheat, barley, maize, &c. among the cereals, pulses, dals, and spices. Rice is rarely used. Ghee is eaten by the well-to-do classes; fish is eaten by all classes.

Mahomedans refuse pork, and think beef indigestible. Hindoos, except those who believe in transmigration, eat fish and kid. The daily quantity eaten by a labourer is 2 lbs. of attah, 4 ozs. of dal, and 8 ozs. of vegetables. When ghee is used, 2 ozs. suffices. The health is sustained on these quantities if the foods are properly prepared. Diarrhœa and cholera prevail in the melon-season. The jail diet consists of 20 ozs. of wheat attah, 4 ozs. of dal, 4 ozs. of parched corn, and 67½ grains of salt; 90 grains of oil and 8 ozs. of vegetables are given twice a week. The prisoners enjoy average health, but suffer from emaciation, impaired assimilation, and sloughing of the cornea, as the result of a deficient supply of oil; also boils and skin-diseases from deficiency of fresh vegetables.

58. Dr. G. Grant, Futtehgurh, states that vegetable food is the staple dietary, and that animal food is rarely consumed. The dietary contains cereals, legumes, fresh vegetables, fruits, milk, with its preparation of ghee, dhy, rubree, and sugar; the two latter are not obtained by the very poorest. Fish are not eaten, except when they can be readily caught, as during the rains. The daily quantity of food for an outdoor labourer is 24 to 32 ozs. of attah (flour from the cereals) and legumes, 4 ozs. of pulse, and 8 to 12 ozs. of vegetables: artisans and indoor labourers eat less. There are two meals daily, at about noon and sunset. The flour is made into unleavened cakes or into porridge. Parched unground grain is eaten when travelling, or when unable to cook. The dals are split, and then boiled, and eaten with ghee or garlic, &c.; vegetables are stewed with water, ghee, or oil, salt, and condiments; meat is boiled with salt and condiments; fish is fried with oil, salt, and condiments; curds are produced by curdling warm milk; ghee is obtained by constantly agitating curdled milk; rubree is produced by evaporating milk. Wheat is regarded as wholesome and nutritious; dals as heating; potatoes as hot and very digestible; onions and garlic as hot and stimulating, and purifying the blood; carrots, turnips, &c. as cold and strengthening, but not of easy digestion; melons as hot, and increasing appetite; milk and its preparations as heating, nutritious, and constipating; animal food as heating, nutritious, and digestible; and fish as more heating than meat. The jail diet resembles the free labourers' diet, and varies with labour and day of the week; the effect upon health and strength is good. (Diet No. 21.)

59. Dr. G. Bernard, Mynpoorie, quotes the kinds of food which are eaten, and the average quantity, but does not give a daily dietary. The Mussulman population is in good health. The very poor are liable to scurvy, bowel-complaints, and skin-disease. The jail diet varies with labour and day of the week, and the prisoners keep in health and strength. (Diet No. 21.)

60. Dr. J. Sheetz, Etawah, states that about 2 lbs. of wheat-flour is eaten daily, except by the very poor, who eat grains inferior to wheat in gluten, as jowar and bajra, and then fall into ill-health, as shown by the coarse and scaly epidermis, pale conjunctiva, large abdomen, and deficient muscular development. The jail dietary varies with sex and labour. (Diet No. 21.)

61. Dr. H. S. Smith, Goruckpore, states that the neighbourhood is very fertile, and produces all tropical and European vegetables. The natives eat two meals daily, at noon and at eight or nine P.M., the former consisting of parched corn or young maize, and the latter of rice, jowar, or chapattees, made from wheat- and barley-flour, with dal, mustard-oil, or curry-powder, fish, ghee, and milk. Fish is very abundant, and yet is often eaten when putrid, also raw vegetables (Cucurbitaceæ), causing epidemics. 8 ozs. of Indian corn is eaten at the morning meal; and 24 ozs. of rice, wheat, or barley is enough

for the day. The jail dietary varies with labour and day of the week; it is ample. (Diet No. 21.)

62. Dr. J. H. Loch, Mirzapore, states that in cities the first and second classes eat 12 to 16 ozs. of wheat-flour, 4 ozs. of rice, 4 to 6 ozs. of dals, 4 to 8 ozs. of vegetables, and $\frac{1}{2}$–1 oz. of pickles and ghee. The richer the man, the more ghee and rice he consumes. The third class eat bread of barley-flour, and not soaked in ghee; some have only one meal daily. The dietary consists of 24 ozs. of flour and 6 to 8 ozs. of dal; and when parched grain is eaten, the quantity is 8 to 16 ozs.; and when they have rice, they eat about 8 ozs. at each meal. The fourth class have still coarser food; and the quantity is, flour 2 lbs., dal 4 ozs., and parched grain 8 to 16 ozs. Nearly all eat meat and fish occasionally, when they can afford it; and the Kayasts (Hindoos) eat about 1 lb. of goat's flesh daily. In the country, the first and second classes use wheat-flour; and the daily quantity is, flour 1 lb., dal 4 ozs., rice 8 ozs., ghee 4 ozs., milk 1 lb., vegetables 2 ozs. The third class eat barley-bread, and consume, daily, flour 24 ozs., dal 6 ozs., ghee (when used) 2 ozs., rice 20 ozs., and vegetables 8 ozs. The fourth class live very poorly, and the food consists of flour 24 to 32 ozs. and dal 4 ozs. The jail diet varies with labour and day of the week; and the prisoners gain weight upon it. (Diet No. 21.)

63. R. Cockburn, Esq., Allahabad, states that wheat, barley, bajra, jowar, &c. are the principal grains; rice is but little eaten; maize is seldom eaten as bread, but is roasted whole in the ear before it is quite ripe; dals are generally used. The daily dietary is not given.

Oude.

64. Dr. J. C. Whishaw, Oude, describes at great length the various foods in use. He remarks upon the difficulty of obtaining exact information. Poverty is common, but destitution very rare. A very large proportion of the poor scarcely ever cook, but live for weeks on *suttoo*, cheap fruits, with such seeds as they collect. Some keep pigeons, which, having collected grain, are made to vomit it up for human use. The unchanged grain is washed out of the dung of oxen when treading out the corn. This class is very liable to disease. *Kunjers*, living in jungles, will eat jackals, snakes, wild cats, and every kind of animal and vegetable food. Mussulmen eat all ordinary food, except pork. Buffalo-flesh is cheap, and the animal must be killed with the proper ceremonies. The low-caste Hindoos eat the flesh of animals dying naturally, and pork largely. Brahmins, &c., may eat any game, as deer, porcupines, birds, and flesh. Some *Chuttrees* eat goat's flesh. The high-caste Hindoos do not eat onions, and some refuse garlic or turnips. Among all castes there are *Bhaghuts*, who swear not to eat meat or drink intoxicating liquors. The Chuttrees, earning from 5 to 8 rupees a month, eat daily from $1\frac{1}{2}$ to 2 lbs. of wheat or barley, unleavened bread, with 4 ozs. of boiled dal and some chillies. They cook only once a day, and eat only parched grain at other periods; very few eat meat daily; fish is a more common diet; milk is not a universal food; ghee is always eaten when it can be obtained. Some of the rich drink half a pint to 3 pints of milk a day, and become very fat. Eggs are eaten by Mussulmen, and chiefly by the rich; they attach great importance to water, and will say that one is light and wanting in strength, whilst another is good and full of body. Salt is indispensable; lime is eaten daily, either mixed with tobacco or otherwise. There is no well-detailed daily dietary. The jail dietary varies with sex and labour, and to some extent with day of

the week, and is better than that usually obtained in freedom. The prisoners are liable to diarrhœa and dysentery, but it is not due to the dietary. (Diet No. 22.)

65. J. W. H. Condon, Esq., Hurdin, describes the various native races and castes, under the heads of their religion, manner of living, and food. The Hindoos are a much more energetic race than the Mahomedans. The lower castes, as *Parsees*, &c., pursue agriculture, and take but one substantial meal daily, and that is after sunset. They may eat perhaps a little cold bread in the early morning, and at midday they have a handful of parched gram. The lower classes of the Mahomedans are weavers, &c., and eat two meals daily. Mahomedans will eat any flesh but pig, on account of its uncleanly habits, provided the animal had its throat cut; whilst many castes of Hindoos, as Brahmins and Bunneahs, live entirely upon vegetable food. All Hindoos eat chapattee, which is a thin flat cake baked from flour of various grains. The cultivator of the land eats about 24 ozs. of this bread, with an ounce of ghee, a handful of dal, and vegetables; but when very poor, they have scarcely any food but the chapattee. All like sweetmeats, and all eat milk plentifully. There is great want of muscular development; but they are well-formed and have great powers of endurance. They are patient in suffering; wounds readily heal, and yet the people readily sink under severe disease. The jail diet varies with labour, and to some extent with the day of the week. The health of the prisoners is good. Ophthalmia prevails; and yet the diet is better than the majority obtain when free. (Diet No. 22.)

66. Dr. E. Setons, Pertabghur, experienced difficulty in obtaining the information. Some castes (rarely the poorest classes), as *Aheers* and *Gurereas*, occasionally get a little milk, ghee, or buttermilk. *Parsees*, when rich enough, keep and eat pigs. The food is chiefly vegetables, and varies with the three harvest seasons—September, November, and March. The daily quantity of the labourer is $1\frac{1}{2}$ lb. of attah, 4 ozs. of dal, 2 ozs. of ghee, or a little oil, with salt and pepper; green vegetables are eaten instead of dal, in their season. When meat is regularly eaten, the quantity is about 1 lb. per day; but Hindoos, who eat it only rarely, then take a much larger quantity. The labouring classes eat only one meal, and that in the evening; but they have 2 to 6 ozs. of *chabena*, or gram, at other periods. The better classes eat two meals daily. The meat is eaten as stew or curry. Various kinds of corn and legumens are ground into flour and made into chapattees; they are smeared with oil or ghee, and eaten with dal or green vegetables, which are boiled with oil or ghee. The diet is deficient in fat and flesh; the leguminous seeds are very important. The large quantity of food eaten at one meal is injurious, leads to chronic dyspepsia, and retards convalescence from disease. The jail diet is varied with labour and somewhat with the day of the week. (Diet No. 22.)

67. Dr. G. W. Bonavia, Durriabad, states that a labourer, working in the fields from eight to ten hours daily, eats of wheat or other flour $\frac{3}{4}$ to $1\frac{1}{2}$ seer*, rice $\frac{1}{2}$ to $\frac{3}{4}$ seer, dal 2 to 4 chits., ghee $\frac{1}{4}$ to $\frac{1}{2}$ chit., salt $\frac{1}{4}$ chit., condiments $\frac{1}{19}$ chit. Wheat is preferred, and the coarse bran only is taken out; the flour is made into chapattees. Some grains are used both as flour and as dal, and are eaten as the latter, with 1 or 2 ozs. of ghee, by all but the poorest. Goat's flesh or fish is eaten from three to twelve times a year in quantities from $\frac{1}{4}$ to $\frac{3}{4}$ seer. Most villagers keep cows or buffaloes, and take the milk, ghee, or butter for their own use, the latter in quantity of $\frac{1}{4}$ to 1 seer daily, or two

* Pukka-weight.

or three times a week. They use about $\frac{1}{4}$ of a seer of vegetables three or four times a month, and parched corn, to the extent of $\frac{1}{4}$ seer, is eaten every third or fourth day. The above are the standard quantities; but less is taken by the coolies, who are very poor and seldom able-bodied.

68. Dr. C. Lowdell, Gonda, states that the customary food is fish (abundant all the year), goat's flesh, mutton, and other meats, with vegetables. Dal and rice are the staple food; fish and flesh are cooked in one mess with the vegetables, dal, condiments, and ghee or oil. The cost of foods is given. The jail dietary varies with labour, and somewhat with the day. The attah is composed of half wheat and half barley. The prisoners have been healthy. (Diet No. 21, nearly.)

69. E. C. Bensley, Esq., Baraitch, experienced difficulty in obtaining the information. He does not give a daily dietary. The jail dietary varies with sex and labour, and somewhat with the day. (Diet No. 22.)

70. Dr. J. Ellis, Oonao, states that the food is almost entirely vegetable, and is derived from the Gramineæ and Leguminosæ. Wheat, barley, rice, maize, peas, and vetches enter into it. About $1\frac{1}{2}$ to $1\frac{3}{4}$ lb. of wheaten bread is used, and this is the staple food. The jail diet varies with sex and labour, and somewhat with the day. (Diet No. 22.)

71. Dr. F. Carter, Lukhimpore, gives a list of the various grains, vegetables, and fruits in use. Wheat is most used by the better, and barley and Indian corn by the poorer classes. Of fresh vegetables, potatoes and yams are most abundant. Diarrhœa, dysentery, goître, enlarged spleen, dropsy, and fever prevail. The diet varies with sex, labour, and day of the week, and is well suited to the prisoners. (Diet No. 22.)

72. A. W. Baillie, Esq., Seetapore, states that the agricultural labourers constitute the mass of the people, who are Hindoos, and receive their pay chiefly in kind. Grain is almost the whole food of the lower classes; green vegetables are little used by the lower classes, though they grow freely, and meat is not eaten. They are tall, vigorous, and frequently powerful men. Their diseases are not those of nutrition. The jail dietary varies with age, labour, and day of the week, and maintains health. (Diet No. 22.)

73. Dr. H. M. Cannon, Inspector of Prisons, Oude, offers observations upon the diet and diseases of prisoners, and considers that the Punjab prison dietary is as complete and wholesome a scale as can well be followed. It contains 3·7 of carboniferous to 1 of nitrogenous food. (Diet No. 22.)

74. Dr. W. Constant, Sultanpore, gives a short description of the district, and then states that the diet is essentially a vegetable one. Wheat is abundant and fine, and is the staple food; rice is very little eaten; various other grains are made into bread. All dals, if eaten in excess and with their skins, cause diarrhœa, &c. Vegetables and fruit abound. All Mussulmen eat the meat of the cow, buffalo, camel, goat, sheep, hare, wild-fowl, game, and fish. All Hindoos, except Brahmins and Bhagats, eat the flesh of sheep and goats when they can get it, and are fond of fish and fowl. Sugar-cane is chewed, and fattens; spirits are drunk largely, and intoxicating drugs are eaten by low-caste Hindoos. The Talookdars usually eat meat, thin chapattee, and the finest dal, and take two meals daily. The landholders and tradespeople live chiefly on vegetable food, and eat at two meals much more than that eaten by a European; but they do not drink generally, and their health is good. The agricultural labourers and the very poor live on inferior grains, pulse, and vegetables, and eat flesh when they can get it; they are very insufficiently fed and sheltered. Such eat but once a day, and that at noon; and their health is not good. He cannot give a daily dietary. The jail diet

varies with sex, labour, and somewhat with the day of the week, and maintains health. (Diet No. 22.)

Sirbund and Meerut.

75. G. Harper, Esq., Umballa, states shortly the foods in use. The quantity of flour or rice consumed daily varies from 1 to 2 lbs.; and the health is good. He does not give a daily dietary. The jail diet consists of 48 ozs. of attah daily, 4 ozs. of dal weekly, and 1 oz. of ghee thrice a week.

76. Dr. W. P. Harris, Budaon, gives a statement of the kind of food, with the quantity of each, and the effect upon the body; but it is not stated whether the quantity is per day or per meal, and no daily dietary is given. The jail dietary varies with labour. (Diet No. 21.)

77. Dr. C. T. Paske, Saharumpore, enters largely into the consideration of the various animal and vegetable foods in use, with their modes of preparation and effects upon the body. Chapattee is the staple food, as bread is in England, and is eaten with ghee by the wealthier classes. The poor cannot obtain ghee. The quantity of this "attah" which is eaten daily is from 1 to 1½ lb.; barley is less eaten than wheat; oats are not used by men; maize is largely grown and used; rice is largely eaten; the refuse of sugar, "gour," is much eaten, as is also the sugar-cane itself; potatoes are cheap, and universally used; onions and garlic are used in making curry; spices are used extensively, and are a remedy for their weak digestive powers, induced by long fasts and badly cooked food; animal food is occasionally eaten, but not nearly so much as in cold climates; the flesh eaten is that of the cow, pig, goat, sheep, and some kinds of game; ghee is eaten with every food, and even alone, and the more rancid the better. As a man can afford it, he becomes fat. Salt, milk, and eggs are also largely used. The water used is usually from wells; spirits and intoxicating drugs are largely used. The jail dietary varies with labour and the day of the week, and agrees with the prisoners. (Diet No. 21 very nearly.)

78. Dr. Isaac Newton, Kurnaul, shortly describes the various grains in use, and states that wheat, barley, and rice are the most valued. He does not give a daily dietary, but states that 2 lbs. of all the foods together is the daily quantity, eaten at two meals. The jail dietary varies with labour, and consists of 16 to 20 ozs. of attah and 4 ozs. of dal; vegetables twice a week, instead of dal; oil 45 grains, salt 67 grains, and chillies 37 grains. The imprisonment does not exceed one month, and the health is not injured.

79. J. M. Cunningham, Esq., Bareilly, refers only to jail dietary, and shows that it varies with sex, labour, and day of the week. Attah is made with three-fourths wheat (of second quality) and one-fifth barley, and the husks of both remain in the flour. He says, "It is one of the great sources of complaint among prisoners that the unsifted flour disagrees with them; but the complaint is unjust, as it is very unusual for any free man, unless in easy circumstances, to have his flour sifted before using it." 20 ozs. of attah should make 28 ozs. when cooked into chapattees. In addition to the regular diet, which is prepared at 3½ P.M., when work is over, he has 4 ozs. of parched grain, which he eats in the morning. Women and boys under æt. 15 have the diet of the non-labouring class. The jail dietary is sufficient. (Diet No. 21.)

80. Dr. J. Hutchinson, Dehra Doon, states that 28 ozs. of attah is consumed daily (16 ozs. in the morning and 12 ozs. in the evening). Some prefer 14 ozs. of rice for the morning meal; also 6 ozs. of dals (when not supplanted by vegetables); ¼ to ½ lb. of meat is eaten occasionally by Mahomedans and low-

caste Hindoos, and fish when procurable. Milk and curdled milk ("dahee") are largely consumed, and chiefly by the Hindoos; vegetables are freely eaten; parched grain and oil are much desired, and this food maintains health. The diet of the poorer classes varies much, as their income and the prices of food vary. The jail dietary varies with labour and day of the week, and maintains health and strength. (Diet No. 21.)

81. Adam Taylor, Esq., Rohtuck, quotes the different kinds of food in use, but does not give the daily quantities. The jail dietary varies with sex and labour, and somewhat with the week. Barley may be mixed with the wheat in the proportion of 4 to 35 parts. 1 part of bran out of every 40 parts of attah is taken out. Labouring prisoners have 4 ozs. of parched gram daily, except on Sundays. (Diet No. 22.)

82. Dr. F. Parsons, Hissar, states that wheat is given most abundantly, and is preferred to many other grains; barley stands next in order. Rice is eaten by all classes; curdled milk, ghee, and buttermilk are also eaten.

83. W. B. Butt, Esq., Loodiana, gives four valuable tables of the daily quantities of food. The field-labourers eat daily, in the hot weather, flour, made into unleavened chapattees, about 2 lbs., gram dal 10 ozs., parched gram 4 ozs., melons, sugar-cane, and buttermilk in large quantities, and ghee ½ oz. In the cold weather, about 3 lbs. of flour from inferior grains, 8 ozs. of *moth dal*, 4 ozs. of parched grain or Indian corn, 8 ozs. of fresh vegetables, ½ oz. of ghee, and much buttermilk. The ordinary diet of caste-men, *Chumars* and *Sweepers*, &c., consists of flesh, including pork, largely stewed with vegetables and condiments, ½ oz. of ghee, 2 lbs. of flour of wheat and other grain, 4 ozs. of parched grain, and large quantities of raw vegetables and of buttermilk. That of the *Cashmeeres* is flesh, except pork, about 8 ozs., milk half-pint, cream 1 oz., rice 1 lb., green tea 1 dr., large quantities of fresh vegetables, 1 lb. of wheaten bread, and 1 oz. of mustard-oil. The *Jat Siekhs* are strong, hardy, and industrious, and live chiefly on vegetables, eating flesh only a few times yearly; they do not usually drink spirits. The *Punjabee Mussulmen* are similar, but eat flesh two or three times a month. The *Chumars* are inferior; they eat less bread and dal, but more meat, and often that of dying animals; they eat opium and drink spirits. The *Sweepers* are rough and strong, and eat flesh, particularly that of a lizard, "Sanda." The *Cashmeeres* are of good height, well made, and muscular; when they work out of doors they are healthy, but they generally are shawl-makers and of dirty habits; they live well, and do not take opium or spirits. They are liable to ophthalmia, scrofula, and diseases of the lungs. The jail diet varies with labour and day of the week, and the prisoners are healthy. (Diet No. 22.)

84. J. Brake, Esq., Simla, states that the daily dietary of a strong man is wheat or Indian flour 2 lbs. and dal 4 ozs., or rice 24 ozs. and dal 4 ozs., with a variable quantity of vegetables. An old man eats 16 ozs. of the cereals and 4 ozs. of dal; milk and ghee are eaten sparingly on account of the cost; wild birds, wild pigs, and goats are eaten freely when obtainable. The jail diet is attah 16 ozs., dal 4 ozs., salt 4¼ murhas; but the prisoners are detained only a few days.

85. Dr. R. A. Minas, Bhutty Territory, states that the district is arid, and the crops small and uncertain; hence the poor often subsist on wild fruits, bark, and seeds, and seek for quantity rather than quality. Wheat is the staple food, and about 20 oz. of it is eaten. When rice is preferred, the quantity consumed is 1 lb. He describes numerous articles of food, but does not give a daily dietary. The jail dietary varies with sex and labour. The bran is carefully taken from the wheat to the extent of 1 to 1½ seer in a

maud, to prevent the occurrence of diarrhœa. The chapattees are cooked in ovens sunk in the ground; 5 parts of barley may be added to 35 of wheat. Ghee is given, instead of oil, to prisoners sentenced to more than six months' imprisonment; and vegetables are given twice a week. The prisoners are better fed than free labourers. The jail manual contains some valuable directions. (Diet No. 22.)

86. Dr. J. L. Stewart, Bijnour, gives a lengthened and interesting account of the locality, and of the various foods in use. The consumption of wheat, pulse, &c. is much greater in spring and summer, when they are abundant and cheap. Of all cereals, wheat and rice are in the highest repute, and are the staple food. It is to be regretted that, with so much information, the daily dietary and quantity of food is not given. It is only stated that with 20 or 24 ozs. of bread or rice, with pulse, the Hindoo will eat 3 to 4 ozs. of flesh; also, that the average daily food is 20 to 24 ozs. of the cereals and 4 ozs. of pulse. The average weight of prisoners is, *Hindoos* 100 lbs., *Mussulmen* 96 lbs.

87. Dr. C. O. Daniell, Hoshyarpore, gives a list of numerous foods in use; their local, English, and scientific names; the extent of their cultivation and mode of preparation, and, in some instances, the amount of them which is eaten daily. There is not, however, a daily dietary given.

88. Dr. C. N. Bose, Thung, states that wheat and other grains are made into thick cakes. The bread is eaten with dal and sag, with vegetables and condiments. Meat is eaten only very occasionally, or when a diseased animal is killed. They drink water or buttermilk. There are two meals daily, viz. at 7 A.M. and 7 P.M. in the hot, and 9 A.M. and 8 P.M. in the cold season, and they consist of about 40 ozs. of food. The people are generally healthy, but liable to diarrhœa from the use of fruits and coarsely ground grains. The industrial classes obtain more animal food, and take from 24 to 32 ozs. of food daily. The jail dietary varies with sex, labour, and day of the week, and consists of attah 20 ozs., dal 2 ozs., salt $67\frac{1}{2}$ grains, and chillies 37 grains, daily, with 8 ozs. of vegetables and $\frac{1}{4}$ tollah of oil weekly, besides 2 ozs. of parched grain given to the labouring prisoners. Women have the diet of the non-labouring class. The food is not prejudicial to health. (Diet No. 22 nearly.)

89. Dr. C. F. Oldham, Googaira, states that the inhabitants are Mussulmen, and consist of the pastoral tribes, who wander about and live in reed huts in the jungle, and also of the agricultural and trading classes. Milk, fresh or curdled or as buttermilk, is the most important food of the pastoral tribes; and when they can, they obtain attah, with ghee. They say, "A man may live without bread; but without buttermilk he dies." They do not cultivate vegetables, but eat them when they get them. Curries are not common, and chillies are not much used. The daily quantity of food is, milk or buttermilk 4 to 6 lbs., attah 12 to 16 ozs., and ghee 2 to 4 ozs.; dal is seldom used, and beef and mutton only occasionally; sugar or molasses is mixed with milk; alcohol is seldom, and opium never, used. Among the industrial tribes milk is still used to the extent of 2 lbs., attah from 16 to 22 ozs., and 2 to 4 ozs. of ghee. Vegetables are eaten in large quantities, and chillies daily; dal is seldom used; spirits and tobacco are largely consumed, and opium is taken chiefly in towns. Another class, *Chhura*, do the dirty work of the community; they eat much milk and attah, besides the flesh of snakes, lizards, and reptiles, wolves, jackals, horses, and cattle, which have died naturally. They cut the flesh into strips, and dry it in the sun when not required for use. The pastoral tribes are one of the finest races in India, tall, straight, muscular,

handsome, active, enduring, and brave; they regard the agricultural class with contempt. The agricultural class are also a fine race and healthy. The *Chhura* or *Sweeper class* are very healthy and robust. The jail dietary varies with sex, labour, and day of the week; it is sufficient, although less than that to which they are accustomed. The chief diseases are those of the bowels and lungs. (Diet No. 23.)

90. Dr. W. A. Green, Leia, states that the food of the labouring and industrial classes is chiefly farinaceous, and a never-changing sort of meal. Animal food is a dainty luxury, eaten only on special days. Wheat, maize, barley, jowar, and súrwar are usually made into cakes. The quantity of grains or pulses eaten is 2 lbs. to 3 lbs. daily. Dals are seldom or never used by these classes. Turnip is the favourite vegetable, and vegetables and fruits are largely eaten. Milk, butter, and buttermilk are very extensively used; the latter is regarded as indispensable, and they prefer it to a meal. Those living on the Thull (the sandy and unproductive districts) live solely upon milk, especially camel's milk, which is brackish, has but little fat, and is drunk diluted with water. It is laxative to those unaccustomed to its use. The people are hearty and vigorous, sturdy and robust. The sameness of food has no bad effect. In jails the diet is too little and too limited, leaving out the indispensable buttermilk (which is antiscorbutic) and fruits, and forcing upon the prisoner the dals to which he is not accustomed. Want of free exercise is also another cause of evil. It is a great misfortune that the daily quantity of food is not given, seeing that the dietary is peculiar.

91. Dr. T. McShahy, Dera Ismail Khan, gives a table showing the kinds of food in use, and the daily quantity of each which is eaten; but as all are not eaten on the same day, the daily dietary cannot be inferred from it. The daily ration of rice is 2 lbs., but it is seldom eaten; of the usual grains 2½ lbs.; of meat 1 to 2 lbs., but only eaten very occasionally; of buttermilk 10 lbs., used as drink; of milk 2 lbs.; of ghee 4 ozs.; and of various vegetables from 2 to 4 lbs. Onions are seldom eaten. The jail dietary varies with sex, labour, and day of the week. (Diet No. 23.)

92. Dr. S. A. Homan, Tallunder, states the nature of the diet of the different classes in hot and cold weather, with the quantity of each eaten daily, the mode of preparation, and the frequency of their use; and supplies the daily dietary of the different classes. The higher-class Hindoos at all seasons take 16 ozs. of attah of wheat, or 12 ozs. of khichree, with 4 ozs. of dal and 2 ozs. of ghee, daily; also 12 ozs. of rice and 8 ozs. of vegetables now and then; and a few eat occasionally 8 ozs. of meat. The lower-class Hindoos take in cold weather 2 lbs. of Indian corn or other grain for making *rotee*, 4 ozs. of dal (or 8 ozs. of vegetables now and then), 1 oz. of ghee, and some of them 24 ozs. of attah of wheat, if procurable. In hot weather, 2 lbs. of attah of barley, &c. is substituted for Indian corn, &c. The higher-class Mussulmen eat, in both hot and cold weather, 16 ozs. of attah of wheat in chapattees, 8 ozs. of rice, 8 ozs. of meat (for boiling), 8 ozs. of vegetables, 4 ozs. of various dals, and the ghee used in frying the food. The lower class in cold weather eat 2 lbs. of Indian-corn attah or other grain, or 24 ozs. of attah of wheat, with 4 ozs. of various dals, 8 ozs. of vegetables and some ghee, with 8 ozs. of meat now and then. In hot weather 2 lbs. of attah of barley, or *Baisnee rotee*, is substituted for other grain. The jail dietary varies with labour and day of the week; it consists of 20 ozs. of attah of wheat for making chapattees, or 12 ozs. of rice, 4 ozs. of dal, or 8 ozs. of vegetables twice a week, 1 oz. of ghee, 80 grains of salt, and 2 massalahs of chillies. This is a very valuable report. (Diet No. 23 nearly.)

93. Dr. J. C. Penny, Madhapore, gives a list of the articles of food in use, with the daily average quantity of each which is eaten (when they are eaten), the mode of preparation, and other remarks upon them, but does not give a daily dietary. Barley is used chiefly by the poor, and is surreptitiously mixed with the attah of wheat; but there is much prejudice against its use. Rice is not a common food. Dal is used universally. The cow yields but little milk; so that the supply of milk is chiefly from buffaloes and goats, and it is eaten by the prosperous classes only. Ghee is sometimes used externally as an inunction. Beef is confined to Mahomedans, and pork to the Seikhs. Mutton is plentiful, and generally enjoyed. The jail dietary varies with sex, labour, and day of the week. (Diet No. 23.)

94. Dr. G. A. Watson, Shahpore, gives in detail the articles of diet used in the jail. The dietary varies with duration of imprisonment. Oil is given only to those sentenced to *less* than six months', and ghee to those sentenced to *more* than six months' imprisonment. He also supplies a long list of the articles of food, and of the nitrogenous substances eaten by the free inhabitants, with a statement of the cultivation, consumption, and mode of preparation; but he does not give a daily dietary.

95. Dr. H. N. Elton, Sealkote, gives a similar list of foods, with a statement of the daily quantity of each when eaten, the mode of preparation, and the effect upon the health, &c., but does not quote a daily dietary. Attah of wheat is eaten by all classes, at 10 A.M. and 8 P.M., in a quantity of 2 lbs. daily. It is made into cakes, baked in an oven or pan, and smeared with ghee. Gram, barley, &c. are generally eaten by the working zemindars. Dal and certain vegetables are eaten by all classes. Rice is not a daily food, but is used at entertainments. Goats, sheep, fowls, and fish, in quantity of 1 lb., are eaten by all classes, but not daily by the poor. Milk and buttermilk are used in quantities of 24 ozs. daily. The jail dietary varies with sex, labour, and day of the week. (Diet No. 23.)

96. Dr. G. Henderson, Thelum, gives a list of foods eaten by the inhabitants, both free and in jail, with a short statement of the mode of preparation, but does not quote the daily dietary.

97. Dr. R. Parker, Kangra, states at length the various foods eaten in his district, with the daily consumption, mode of preparation, influence upon health, &c., but does not give a daily dietary. Rice is eaten by all classes at midday; wheat-flour by the higher class, and by Cashmeeres and Mussulmen all the year, and by Hindoos in the hot and rainy seasons. Maize is principally eaten by the zemindars, except in the hottest season; millet only by the poorer classes; barley-flour chiefly by the zemindars; dal and condiments by all classes, and vegetables by all classes at times. Meat is eaten in all seasons; carrion in quantities of 1 lb. at a time; and all flesh, except that of jackals and dogs, agrees with them. Tea is sometimes used, morning and evening. The jail diet varies with sex, labour, and day of the week, and is ample in quantity and excellent in quality. Weevil and bran should be, and are, excluded from the wheat-flour.

98. Dr. T. S. Neale, Goojranwallah, gives a very similar report, and does not cite a daily dietary. Wheat-flour and the best kinds of rice are eaten by the opulent classes; this, with barley-meal, maize, and inferior rice, by the inferior classes. Milk is drunk in enormous quantities by the Sheikhs, and these, with the Mahomedans, are the chief consumers; it is scarcely attainable by the poor. Ghee is not obtained by the poor except in very small quantities—once in ten or fourteen days, and often not for a year. The poor obtained damaged, but not sound, meat. The quantity of each, when eaten,

is 2 lbs. of the cereals, 6 to 8 ozs. of dals, 2 to 4 ozs. of milk, 2 to 4 ozs. of ghee, 8 ozs. of butter, 16 ozs. of meat.

99. M. L. Hug, Pindadun Khan, supplies a list of the articles of food, with their cultivation, consumption, and mode of preparation, but does not give a daily dietary. Wheat is the principal food of all classes; rice is eaten by the rich, and barley by the poor. Indian corn is not usually eaten by the poor, but is given to horses. The sugar-cane is used by all classes for its juice, and vinegar is made from it. Cauliflowers, cabbage, and potatoes are neither cultivated nor eaten; turnips, radishes, mustard, onions, garlic, carrots, &c., are used by all. Mutton is only of middling, whilst beef is of bad quality: both are eaten by Mahomedans, and the former by some Hindoos (not Hindoo women), and much is consumed. Fowls and eggs are scarcely used. Ghee and milk are plentifully consumed by all. Fish is very scarce. The higher-caste Hindoos live totally on vegetable food, excepting milk and ghee, and are healthier than others. The agriculturists live on chapattees (from grain-flours), raw onions, and *lussee*. The middle classes take all kinds of food.

Burmah.

100. B. Hooker, Esq., Tavoy, Burmah, states that rice is the most important and the principal aliment, and is not of the best quality, and induces obstinate constipation, with its consequences. Masticated rice is given to infants, and destroys nearly all which are not strong and healthy born. The ordinary flesh in use is from the elk, and is fresh or dried; but the Burmese will eat the flesh of elephant, tapir, and rhinoceros, and the *Karens* that of monkeys and some kinds of snakes. Fish is very plentiful, and is kept closely packed in vessels until it decomposes, causing choleraic symptoms. There is no endemic disease. Tea is used at every meal when it can be afforded. The Chinese eat more meat than the Burmese, and take a glass of spirits before meals. The daily dietary of a Chinese consists of rice 24 ozs., pork 8 ozs., fish or flesh 4 ozs., vegetables 8 ozs., condiments $1\frac{1}{2}$ oz., ghee or oil $\frac{1}{2}$ oz., pickles $\frac{1}{2}$ oz., salt 1 oz., tea 1 oz., and arrack 8 ozs.: that of a Burmese contains rice 2 lbs., fish or flesh 8 ozs., vegetables 6 ozs., condiments 1 oz., ghee or oil $1\frac{1}{2}$ oz., salt $1\frac{1}{2}$ oz., tea $\frac{1}{2}$ oz., and gnapé 3 ozs. The jail dietary varies with labour and day of the week. (Diet No. 24.)

101. R. T. Suffrein, Esq., Tounghoo, states that the natives there consist of *Burmese, Shans,* and *Karens,* the dietary of the latter differing from that of the two former. The Burmese live on rice and vegetables seasoned with curry-stuffs, with considerable quantities of fish, and the flesh of animals dying naturally, except that of the dog and cat. Their religion prohibits them from taking away life. Fish is dried, salted, or smoked. Prawns and small fish are beaten to a paste, and are an important article of diet. Fruits, both ripe and unripe, are eaten largely. The Burmese are muscular and enduring, and are very temperate. The Karens eat chiefly rice and vegetables, besides large quantities of beef, pork, poultry, and game, with a little fish. They are intemperate, and a less robust race than the Burmese, although eating more nutritious food. The jail dietary is similar to that in freedom, and causes increase of weight. The daily diet in freedom consists of rice 29 ozs., fish, flesh, or gnapé 11 ozs., vegetables 14 ozs., ghee 1 oz., oil 1 oz., salt 1 oz., curry-stuff 1 oz.: that in jail contains rice 26 ozs., fish, flesh, or gnapé 3 ozs., vegetables 14 ozs., oil 1 oz., salt 1 oz., and curry-stuff 1 oz., and does not vary with labour.

102. A. Thomas, Esq., Kyouk Phyoo, states that the dietary is similar to that in Lower Bengal, but is prepared differently. Rice is the chief food, and is eaten in quantities of $1\frac{1}{2}$ to 2 lbs. daily; their gnapé having an abominable smell, and made by pounding shrimps, prawns, crabs, or fish. Fish and vegetables are eaten generally. The curries will weigh $1\frac{1}{2}$ lb. to 2 lbs. daily; and besides these, they eat sweets and fruits at all hours. The people are muscular, robust, and enduring. The jail dietary varies with labour and day of the week. (Diet No. 11.)

103. C. E. Pyster, Esq., Sandoway, states that the daily dietary of a labouring man consists of rice 2 lbs., fish or flesh 3 ozs., gnapé 1 oz., vegetables 10 ozs., salt $\frac{1}{2}$ oz., chillies &c. $\frac{1}{2}$ oz.: that of the Bengalese contains rice 24 ozs., dal 4 ozs., or fish 4 ozs., vegetables 2 ozs., mustard-oil 1 oz., spices 1 oz., and salt 1 oz. The jail dietary varies with labour, and in part with day of the week. Very little, if any, ill-effects can be attributed to it. (Diet No. 11.)

104. Dr. G. Marr, Moulmein, in reference to the daily dietary of the free population, has evidently made an error in reducing the native weight to ounces, and instead of dividing by 2 should have multiplied by 2, as may be inferred from the jail dietary. With this correction, the daily dietary of natives of India contains rice 28 ozs., dal 4 ozs., fish or flesh 4 ozs., vegetables 5 ozs., ghee 2 ozs., oil 2 ozs., salt 1 oz., condiments $1\frac{1}{2}$ oz.; whilst that of the Burmans contains rice 40 ozs., fish or flesh 24 ozs., vegetables 24 ozs., oil 4 ozs., with salt and condiments. Rice is the staple food. Dal is not given there. Fish is abundant, and is eaten alternately with flesh of all kinds. Vegetables and oil gengelli are in daily use. The Burmese are short and muscular, and inclined to obesity. They are well fed and contented. Those living in jungles and forests are not so well fed. A Burman will not kill an animal for food, but will eat any dead one. The jail dietary varies with labour, and to some extent with the day of the week. (Diet No. 25.)

105. A. J. Cowie, Esq., Akyab, states that two meals daily are taken. The well-to-do classes eat daily as follows:—best rice 20 ozs., dal 4 ozs., vegetables 4 ozs., oil or ghee 2 ozs., fish 3 ozs., sweetmeats and sugar 3 ozs., salt and spices $\frac{1}{2}$ oz. each. Wheat-flour 16 ozs., cow's or goat's milk $2\frac{1}{2}$ pints. A labourer eats daily, rice 24 ozs., dal 4 ozs., fish 4 ozs., vegetables 6 ozs., salt and spices $\frac{1}{2}$ oz. of each, and meat occasionally 8 ozs., and milk 1 pint daily. Wheat-flour is used sometimes, instead of rice, to the extent of 10 ozs. in the latter class; and I am doubtful whether in the first class both rice and wheat are eaten on the same day, although it so stands in the table. Mussulmen eat meat instead of fish; those of the first class on alternate days. Rice is washed and boiled, and the water thrown away. Dal is boiled with spices, ghee or oil, and salt; fish is generally fried first, and then boiled with spices, ghee or oil, and salt. Vegetables are first fried in oil or ghee, and then boiled; they are sometimes made into curry with meat. Flour is made into chapattees. Meat is fried in ghee or oil, and then boiled with spices and salt. The Arracanees eat daily, rice 28 ozs., fish or flesh 4 ozs., salt, oil, and gnapé $\frac{1}{2}$ oz. each, spices $\frac{1}{4}$ oz., vegetables 4 ozs. They eat much fruit and uncooked vegetables; and more than the above, with any other digestible substance which they can obtain. He states that 167 varieties of rice are cultivated. The jail dietary varies with labour and day of the week. The Sunday's diet is that of the non-labouring class. There are also here two scales of hospital-jail dietary. The jail diet is sufficient and wholesome. Fever, intestinal worms, and dyspepsy prevail. Dr. Snow's views as to the

No. 6			No. 12.	No. 13.				
A.			B.	A.		B.		
Without labour.			With labour.	Without labour.		With labour.		
Senten One to Two				Dr. Mouat's, 1858.				
oz.			oz.	oz.				
Six days.	Sund.	da	Daily.	Mond.	Tues.	Mond.	Tues.	
...	...		...	...	...	...	...	Attah.
17	22		24	22	22	24	24	Rice.
2	4		6	4	4	4	6	Dal.
...	...		...	$1\frac{1}{2}$	...	2	...	Fish or Flesh.
...	1		4	2	2	2	2	Vegetables.
...	...		...	...	...	...	...	Gnapé.
...	$\frac{1}{4}$		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	Oil.
$\frac{1}{4}$	$\frac{1}{4}$		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	Salt.
...	$\frac{1}{4}$		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	Massalahs.
...	...		...	...	...	...	...	Chillies and condiments.

No. 1			No. 25.				
A.	B.		A.		B.		
	With labour.		Without labour.		With labour.		
oz.			oz.				
	›nd.	Tues.	Mond.	Tues.	Mond.	Tues.	
16	..	...	...	...	...	...	Attah.
22	:8	28	24	24	28	28	Rice.
6	4	...	2	2	4	...	Dal.
...	..	...	...	...	...	...	Grain.
4 once a week	4..	4	...	3	...	4	Fish or Flesh.
6	5	5	5	5	5	5	Vegetables.
Ghee $\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	Oil.
$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	Salt.
$\frac{1}{2}$							
...	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	Chillies and condiments.

ay all have the n

APPENDIX.—Showing the Scales of Jail Dietary referred to in this Report.

	No. 1.				No. 2.				No. 3.				No. 4.		
	A.		B.		A.		B.		A.		B.		A.	B.	
	Without labour.		With labour.		Without labour.		With labour.		Without labour.		With labour.		Without labour.	With labour.	
	For Bengalese, Ooryas, and Assamese. oz.				For natives of Behar, North-west Provinces, and the Punjab. oz.				For Coles, Sonthals, Garrows, and all Hill-men and Jungle-men. oz.				For Mughs and Chinamen. oz.		
	Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	All.	Mond.	Tues.
Attah	...	...	...	...	8	8	10	10	...	...	...	...	...	...	...
Rice	18	18	20	20	10	10	12	12	20	18	20	20	22	24	24
Dal	6	2	4	4	4	6	2	6	...	...	...	...	...	...	...
Fish or Flesh	...	...	...	...	...	...	4	...	4	...	4	2	4	4	2
Vegetables	4	8	4	8	6	4	4	4	4	12	8	12	2	4	6
Gnapé	...	...	...	...	...	...	...	...	...	...	...	...	½	½	½
Oil	¼	¼	¼	⅓	¼	⅓	⅓	⅓	⅓	⅓	⅓	⅓	...	...	...
Salt	¼	¼	¼	⅓	¼	⅓	⅓	⅓	⅓	⅓	⅓	⅓	⅓	⅓	⅓
Massalahs	¼	¼	¼	⅓	¼	⅓	⅓	⅓	¼	⅓	¼	⅓	⅓	⅛	⅓
Chillies and condiments		...	...	...	...	...	...	...	...	...	...	...	...	...	...
Totals	15		17		15		17		15		17		15 2/12	17 2/12	

	No. 5.				No. 6.				No. 7.				No. 8.			
	A.		B.		A.		B.		A.		B.		A.		B.	
	Without labour.		With labour.		Without labour.		With labour.		Without labour.		With labour.		Without labour.		With labour.	
	Sentence One Month and less. oz.				Sentence One to Two Months. oz.				Sentence Two to Three Months. oz.				Long term Sentences. oz.			
	Six days.	Sund.	Six days.	Sund.	Six days.	Sund.	Six days.	Sund.	Six days.	Sund.	Six days.	Sund.	Daily.	Every other day.	Daily.	Every other day.
Attah	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Rice	15	22	17	22	17	22	18	22	16	22	18	22	18	...	20	...
Dal	1	4	1	4	2	4	2	4	1	4	2	4	2	4	4	...
Fish or Flesh	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4
Vegetables	...	1	...	1	...	1	1	1	1	1	2	1	4	4	4	4
Gnapé	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Oil	...	¼	...	¼	...	¼	...	¼	⅛	¼	⅛	¼	⅓	...	⅓	...
Salt	⅜	¼	⅝	¼	¼	¼	¼	¼	¼	¼	¼	¼	⅓	...	⅓	...
Massalahs	...	¼	...	¼	...	¼	...	¼	...	¼	...	¼	⅓	...	⅓	...
Chillies and condiments	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Totals																

	No. 9.		No. 10.		No. 11. Scale 1851.			No. 12.	No. 13.				
					A.	B.		B.	A.		B.		
	With labour.		Females.		Without labour.	With labour.		With labour.	Without labour.		With labour.		
	Non-labouring have the same as Sunday's ration. oz.		oz.		And Sunday's diet of labouring. oz.	oz.		oz	Dr. Mouat's, 1858. oz.				
	Daily.	Sund.	Four days.	Seven days.	Daily.	Three days.	Three days.	Daily.	Mond.	Tues.	Mond.	Tues.	
Attah	...	...	...	...	...	...	...	...	...	...	...	...	Attah.
Rice	24	22	18	18	22	24	24	24	22	22	24	24	Rice.
Dal	2	2	4	4	6	2	6	6	4	4	4	6	Dal.
Fish or Flesh	oz. dal 4	oz. dal 4	...	2	...	4	...	...	1½	...	2	...	Fish or Flesh.
Vegetables	4	2	2	2	2	4	4	4	2	2	2	2	Vegetables.
Gnapé	...	...	...	...	...	...	...	...	...	...	...	...	Gnapé.
Oil	¼	¼	¼	¼	¼	¼	¼	½	¼	¼	⅓	½	Oil.
Salt	¼	¼	¼	¼	¼	¼	⅓	½	¼	¼	½	¼	Salt.
Massalahs	¼	¼	⅛	⅛	¼	¼	¼	½	¼	¼	¼	¼	Massalahs.
Chillies and condiments	...	...	...	...	...	...	...	...	...	...	...	...	Chillies and condiments.
Totals													

	No. 14.				No. 15.		No. 16.		No. 17.		No. 18.	
	A.		B.		A.	B.	A.	B.	A.	B.	A.	B.
	Without labour.		With labour.		Without labour.	With labour.	Without labour.	With labour.	Without labour.	With labour.	Without labour.	With labour.
	Dr. Mouat's, 1862. oz.				Women, and boys under 15 years. oz.		Women only. oz.	oz.	oz.		oz.	
	Mond.	Tues.	Mond.	Tues.								
Attah	...	...	...	...	8	10	of wheat 18	of wheat 24	10	12	10	12
Rice	18	18	22	22	8	10	Substituted for flour twice a week 16 ozs.	Substituted for flour twice a week 12 ozs.	8	10	8 once a week in lieu of attah	
Dal	4	6	2	6	4	4	4	5	6	6	4	4
Grain	...	...	...	...	...	...	...	...	...	...	...	...
Fish or Flesh	...	...	4	...	...	...	...	...	...	...	...	...
Vegetables	6	4	4	4	8 twice a week	8 twice a week	6	8	......		8 twice a week instead of dal	
Oil	¼	¼	⅓	⅓	45 grs.	90 grs.	or ghee 90 grs.	or ghee 135 grs.	Ghee 1 oz. once a week. ¼ oz. after conviction.		46 grs. twice a week.	
Salt	½	½	⅓	⅓	90 grs.	180 grs	„ 67½ grs	„ 90 grs.	180 grs. 210 grs. after conviction.		67½ grs.	
Massalahs	½	½	½	½	Tamarind, turmeric, chillies, limes.	Tamarind, turmeric, chillies, limes. Chabene 4.	Chillies 2 Garlic 2 Turmeric 10 grs.	Chillies 2 Garlic 2 Turmeric 10 grs.	Chillies 2. Condiments ¼ oz. after conviction. Tamarind 1 oz.		Chillies 90 grs. Garlic 4 cloves. Turmeric 10 grs.	
Chillies and condiments	...	...	...	...	...	...	...	...	......		......	

	No. 19.		No. 20.		No. 21.		No. 22.	
	A.	B.	A.	B.	A.	B.	A.	B.
					No labour.	Labour.		
	oz.		oz.		oz.		oz.	
Attah	16	18	...	24	Wheat and Barley. 16	20	16	20
Rice	22	24	22	24	...	...	...	...
Dal	6	6	6	6	4	4	4	4
Grain	...	...	...	...	...	4	...	4
Fish or Flesh	4 once a week	4 thrice a week	...	4	...	...	...	
Vegetables	6	6	2	4	...	8 thrice a week	8 thrice a week	
Oil	Ghee ¼	¼	½	½	1/16	1/16	45 grs.	
Salt	½	½	½	½	100 grs.	100 grs.	67½ grs.	
Massalahs	½	½	½	½				
Chillies and condiments	...	...	...	...	No. 1.	No. 1.	36 grs.	

	No. 23.		No. 24.				No. 25.				
	A.	B.	A.		B.		A.		B.		
	Without labour.	With labour.	Without labour.		With labour.		Without labour.		With labour.		
	Women, and boys under 15 years. oz.		oz.				oz.				
			Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	Mond.	Tues.	
Attah	16	20	...	...	...	...	...	...	...	...	Attah.
Rice	......		14	14	28	28	24	24	28	28	Rice.
Dal	4 oz. 5 times weekly		2	...	4	...	2	2	4	...	Dal.
Grain	......		...	...	...	...	...	...	...	...	Grain.
Fish or Flesh	......		...	2	...	4	...	3	...	4	Fish or Flesh.
Vegetables	8 twice a week		2½	2½	5	5	5	5	5	5	Vegetables.
Oil	46 grs. twice a week		¼	¼	½	½	½	½	½	½	Oil.
Salt	67½ grs.		¼	¼	½	½	½	½	½	½	Salt.
Massalahs											
Chillies and condiments	36 grs.		¼	¼	½	½	½	½	½	½	Chillies and condiments.

On Sunday all have the non-labouring rations of Monday.

spread of cholera are supported by facts here: all the outbreaks of cholera have been preceded by a murrain in cattle. (Diet No. 11.)

106. J. J. HEFFERNAN, Thyet-Myo, states that the daily dietary of the free population contains rice 1 to $1\frac{1}{2}$ lb., dal 2 to 3 ozs., fish or flesh 2 to 4 ozs., vegetables 4 to 5 ozs., oil $\frac{1}{4}$ oz. (seldom used), gnapé (nearly always used instead of salt), and condiments. The Burmese, except those addicted to the use of intoxicating liquors and drugs, enjoy average health.

Synthetical Researches on the Formation of Minerals, &c. *By* M. ALPHONSE GAGES.

SINCE my last Report my experiments have been chiefly directed to the synthesis of serpentine and some other magnesian minerals,—to the action of animal organic matter in the production of minerals (a subject which has been often discussed, but is always worth being more fully studied from an experimental point of view),—and lastly, to the action which solutions containing the materials of felspar may have had in altering the composition and structure of Cambrian and other ancient rocks. The results which I propose to give here must necessarily be fragmentary, both from the nature of the investigation itself, and the fact of its being still in progress.

My first object has been to ascertain the kind of action which alkaline solutions exert on the hydrated silicates, of magnesia, iron, and lime, and to endeavour to determine synthetically the formation of serpentine and some other rocks allied to it.

The composition of the mineral known as serpentine is almost constant, while the rock known by that name, though essentially agreeing in composition with the mineral, contains nevertheless various foreign matters. The circumstances under which serpentine-rocks are found and their general character indicate that they are not generally derived from the gradual alteration of a preexisting rock, but have been produced by the direct deposition of silicates which accidentally enclosed foreign substances, and which by dialysis lost alkalies, and by subsequent infiltration may have gained some other constituents and led to the formation of other minerals in the mass.

The process I have employed to arrive at the synthesis of serpentine is based on the *solubility of the hydrated silicate of magnesia* ($2MgO,3SiO_2+4HO$) *in alkalies*, and on the precipitation which results when a diluted solution of bicarbonate of magnesia is added.

1*st Experiment.*—A given quantity of silicate of magnesia in the gelatinous state was introduced into a muslin bag and held in suspension in a diluted solution of caustic potash. After some days the silicate enclosed in the bag was found entirely dissolved. This solution, left in repose in a glass cylinder for some months, deposited a transparent colloid, which, after being washed and dried, presented the following composition:—

Silica	50·036
Magnesia	19·419
Potash	17·642
Water	12·980
	100·077

This substance, when dried, had a semivitreous transparent aspect. Heated to a dull red, it becomes insoluble in acids.

2nd Experiment.—A saturated solution of the hydrated silicate of magnesia ($2MgO, 3\,SiO_2 + 4HO$) in caustic potash, treated by a dilute solution of bicarbonate of magnesia, gives a gelatinous precipitate, which, after having been washed till the action of acids no longer disengages carbonic acid, had the following composition:—

Silica	40·285
Magnesia	38·250
Water............	19·428
Carbonic acid	1·450
	99·413

The substance thus obtained would represent a serpentine with three equivalents of water; it has the composition of the Deweylite of Thompson, which is, in fact, a variety of serpentine.

As the bicarbonate of magnesia which remains in solution with the silicate of potash has a tendency to form with the latter double salts but slightly soluble, it is well to employ only dilute liquors. This tendency of magnesia to replace the alkalies in silicates is exemplified in a great number of hydrated magnesian compounds. On the other hand, the zeolites are in general remarkable by the absence of magnesia; and in one or two exceptional cases, such as the Picrothomsonite for example, in which magnesia enters into the constitution of the mineral, the augmentation of magnesia is attended by a corresponding diminution of the alkalies. Thus serpentine should have been the result of the action of water containing alkalies on magnesian rocks. The same phenomenon is shown on a small scale in certain basaltic tufas, in which we meet with a deposit of magnesian silicate, accompanied often by arragonite and calcareous spar, containing more or less magnesia, while the alkalies of the basalt have completely disappeared *.

Solubility of Silicate of Hydrated Protoxide of Iron.

The silicate of the hydrated protoxide of iron is soluble in the cold in alkalies, if we take care to exclude air; this solution is more readily effected in presence of magnesia, which appears to protect the liquor from further oxidation. We can obtain compounds in which magnesia and protoxide of iron exist in various proportions.

The solutions in potash of the silicates of protoxide of iron, magnesia, and alumina, left exposed to the air on a plate, dry and acquire a gelatinous state without undergoing alteration, the iron remaining in the state of protoxide; the potash separates itself partially from the compound; the substance, then washed and dried, has the form of green scales. Weak hydrochloric acid removes the bases, leaving the siliceous skeleton unaltered, in the shape of soft and nacreous scales like certain chlorites.

The following analysis will give an idea of the solubility of the silicate of protoxide of iron, and of the number of bases which can thus be dissolved and precipitated by evaporation, or by the action of Co_2:—

* Besides the artificial Deweylite, of which I have just given the analysis, I have obtained a great number of other precipitates of variable composition, which strikingly represent the composition of many serpentine-rocks, to which I shall return on another occasion.

Silica	59·004
FeO	13·836
Mo_2O	8·351
Al_2O_3	8·103
HO	11·800
	101·094

The slow metamorphosis which some slates appear to have undergone, and their insensible transition from slate to chloritic slate, show, as I think, the latent part that alkalies have had in that transformation, by their reaction on alumina, protoxide of iron, and magnesia, and also by their faculty of partially separating from the combination once formed. Chlorite always contains more or less alkalies; and even Andalusite found in these rocks often retains traces of alkalies as the last evidence of its mode of formation.

The colloid condition assumed by these aluminous silicates, obtained at a moderate temperature, may lead to the conclusion that the foliated structure assumed by chloritic schists is more or less connected with phenomena of this kind.

Silicate of protoxide of iron dissolved in caustic potash is not precipitated by the alkaline sulphides, and the solution acquires the well-known green tint which the slight traces of sulphide of iron remaining in solution give it when we precipitate a salt of iron by an alkaline sulphide.

Some drops of acid added to the solution of the silicate in the alkaline sulphide give an emerald-green precipitate, which is decomposed with evolution of sulphide of hydrogen on the addition of an excess of acid. The green substance loses its colour as soon as it ceases to be under the influence of the sulphides. A porous body saturated with this solution loses its green tint by desiccation; the colour reappears with a bluish tinge if the substance be exposed to the vapours of sulphide of ammonium. The colour may be thus revived for a certain number of times, after which the phenomenon no longer takes place.

This phenomenon has relation to the natural formation of ultramarine, a substance which is always accompanied by pyrites of iron. The silicate of iron dissolved in the sulphides of potassium leaves upon the side of the glass an ultramarine blue tint; but other circumstances may lead us rather to suspect that this blue colour is due to a molecular condition of the sulphur itself, since a sulphide left to the air in a vase exhibits on the sides of the glass a fugitive blue tint.

Action of the Alkalies on Silicate of Lime.

The direct action of the alkalies, when carbonic acid is not present, on the hydrated silicate of lime is very simple, and may be briefly stated thus:—If the hydrated silicate of lime, $2\ SiO_2\ CaO,\ 2\ HO$, be treated with caustic potash, it loses an equivalent of silica, and becomes transformed into $SiO_2\ CaO,\ HO$; this silicate loses its equivalent of water at a dull red heat, and is then found to have the composition of tabular spar, $CaO,\ SiO_2$.

II. Production of Sulphuret of Zinc, Blende, Selenite, and Calamine, under the influence of Putrefaction of Animal Matter.

The reaction of sulphate of zinc on carbonate of lime or magnesia easily explains the production of Smithsonite, or carbonate of zinc; but when we

inquire into the production of blende and galena in fossiliferous formations, we have to seek this reaction in the compounds of sulphur produced by the decomposition of animal matter, or in the reduction of the sulphates under the same influences. The hydrated silicates of zinc which accompany these minerals prove that other forces were in action at the same time; and the hydrated argillaceous clays which form the metalliferous beds further attest these last reactions.

The sulphides of zinc and lead, the former found in mammillated masses and often in transparent lamellæ, have evidently been formed at the expense of organic matter.

200 grammes of sulphate of zinc, dissolved in two litres of water in which were suspended the fleshy parts of twelve oysters, were enclosed in a bag; with this liquor were introduced some shells, in order to obtain the conversion of the sulphate of zinc into carbonate. The mixture was kept for several months, till putrid fermentation had ceased. The liquor no longer contained zinc; the shells were partially transformed into carbonate of zinc, accompanied by crystals of selenite; the surface of parts of the shells had acquired a transparent rosy tint, produced by a deposit of blende permeating the shell. Left for some time in weak acetic acid (strong acid would decompose it), the transparent rosy tint became more developed; a part of this substance examined was dissolved in hydrochloric acid, with evolution of sulphide of hydrogen, and had the composition and characters of Blende.

Conversion of Carbonate of Lead into Galena.—Some grammes of carbonate of lead recently precipitated were placed in a bag and suspended in two litres of water saturated with carbonic acid; putrid fermentation was kept up in the liquid for some months, in the manner indicated in the last experiment. The shells introduced into the liquid were soon covered with a metallic layer of sulphuret of lead.

A weak solution of chloride of lead treated in the same way gave no result.

Double Sulphate of Copper and Iron.—The double sulphate of iron and copper, by the reaction of carbonate of lime, and under the influence of putrefaction, gave, as the final result, carbonate of iron, blue carbonate of copper in distinct rhomboidal prisms, and semitransparent crystals of selenite.

One of the shells, after treatment by weak acetic acid so as to uncover the surface, left exposed after suitable washing, and on some parts only, spots presenting the metallic grey and the iridescence of the sulphide of copper, and presenting its characters to the blowpipe. The quantity of sulphide found in the mixture was extremely small. The ammonia which is developed during the fermentation must tend to decompose the sulphide of copper and transform it into ammoniacal sulphate. It is what takes place when the sulphide of copper is exposed to the vapours of sulphide of ammonium.

The decomposition of putrescible organic matter of the nature of that employed in contact with sulphate of iron and earthy carbonates leads to different results according to the conditions in which we operate. If we employ a very deep vase and an abundant quantity of water, we obtain sulphide of iron, free sulphur, and carbonate of the protoxide, the sulphate of lime which is formed remaining in the solution. If the vase, on the contrary, present a large surface, the sulphide of iron disappears, and the oxide of iron passes at the maximum of oxidation, and organic matter is consumed. In neither case is the iron pyrites formed, which appears to be the result of a slow reduction of the sulphate of sesquioxide of iron in presence of carbonates.

III. Influence of the Felspathic Solution on the Structure of some Cambrian Rocks.

The schistose deposits of Bray Head, regarded as the lowest stratified beds of the Cambrian system, containing the fossil Oldhamia, considered as the most ancient vestige of animal life on the globe, exhibit a well-marked example of felspathic metamorphism effected by the agency of water. This rock is specially remarkable by the system of joints which it possesses, these joints separating into rhomboidal prisms, presenting the angles of cleavage of the orthoclase felspar, the planes of bedding corresponding to the planes of cleavage of the felspar. Nevertheless, as we might expect in a rock which has been submitted to the influence of other mechanical forces, the angles do not present that exactitude which a crystal of pure felspar would present. Hydrochloric acid does not alter the structure of the rock; after the action of the acid, it can be divided into plates as thin as paper. These plates, examined by the microscope, exhibit a felspathic paste in crystals often distinct, and enveloping grains of sand.

We have here a felspathic solution which has modified a sedimentary rock containing fossils, the existence of which is not contested, and has communicated to it its physical characteristics. Whatever may be the first origin of the felspathic solution, the rock could not be deposited except under the action of water, having its fossils disposed in horizontal layers. The system of joints which this rock presents is not a simple mechanical accident; it is evidently due to the natural arrangement which the molecules of the felspar have assumed when deposited from the solution. It is, in fact, a simple phenomenon of crystallization; that is, the jointing was guided by the planes of cleavage, as being the direction of least resistance.

Microscopic examination after the treatment by acid shows almost always carbonaceous matter in the neighbourhood, or accompanying the prints of fossils, that matter being often enveloped by the felspathic paste.

Metamorphosed Arenaceous Rocks of the same Formation.—As in the preceding rocks, the felspathic solution has sensibly influenced the form which the quartz-rock affects; the crystalline forms of orthoclase predominate at all points. This latter mineral has impressed its mineralogical characters on the rock in a rude manner, it is true, but still sufficiently sensible not to escape observation.

By an analogous phenomenon to that which takes place in the sandstone of Fontainebleau, but in a manner less striking, the active solution percolating through the arenaceous matter has communicated to it its crystalline characters. The prints of felspar, which often show themselves on the surface of these rocks, are sometimes identical in form and in size with the large ones found in the granite locality of Dalkey.

It is not always easy to follow the transition of these felspathic rocks, and there is a moment when they are nearly indistinguishable from rocks considered as granite veins. There is, in reality, no great difference between some of the Cambrian rocks containing a felspathic paste sensibly crystalline and enclosing grains of quartz, and the veins of Eurite filling the cracks and crevices of the Dalkey granite, this paste of Eurite often containing Garnets, and always isolated grains of quartz which could not be developed in it. Logically, I do not see why these veins should not be due to causes analogous to those which have produced the felspar of the Cambrian rocks.

Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours. By ROBERT MALLET, *C.E., F.R.S., F.G.S.*

AT the Cambridge Meeting of the British Association a grant of £100 was made, at the joint recommendation of the Physical and the Geological Sections, to the Reporter, in furtherance of the above-stated research. Since that period a like sum has been granted to him by the Royal Society of London, with the same object.

The estimated cost of the investigation, as carefully calculated as the subject admits, has been found to amount to £350—a sum which so largely exceeds that derived from both grants, that the author felt some hesitation at further pursuing the matter. In view, however, of the fact that the rare occurrence of the peculiarly favourable form of secondary crater existing on Vesuvius might alter at any moment, and perhaps never again present the same facilities for pyrometric experiment, he resolved not to risk the opportunity by losing further time, and to take upon himself whatever pecuniary risk may be involved in performing the task he has proposed, presuming that, should his work prove satisfactory in adding to our positive knowledge of vulcanology, he may be indemnified in some way for such necessary expenditure as may be incurred in excess of the two grants made.

He has, therefore, arranged the whole of the apparatus and instruments required, and their construction is now in progress. These consist of the mechanical arrangements for suspending, passing in over, and lowering into the crater, and again withdrawing, various instruments of greater or less weight; and of the instruments themselves, both for pyrometry and for determining the velocity and state of the issuing blast of steam and gases. The pyrometers finally adopted consist of resistance-coils, with their various electrical arrangements, which are being prepared by Messrs. Siemens, Halske & Co., of London and Berlin, with the able assistance of the author's friend Mr. Charles T. Siemens (C.E., of London); and, as a means of control as well as of separate and distinct determination, instruments have been devised by the author dependent upon Peclet's mode of determining specific heats. By a modification of the arrangements to be employed, the author anticipates being enabled to make the fused lava itself become the means of revealing its own temperatures at points that cannot be directly reached even instrumentally. The latter pyrometric instruments, as well as some of the suspension apparatus, are being prepared by Messrs. Siebe, engineers, of London. A series of thermometers and other minute apparatus are in hand, by Mr. Casella and by Mr. Adie, both of London. For the observation of the velocity of the issuing vapours and gases, the anemometer of Dr. Robinson has been modified in construction and in its metallic material, so as to work satisfactorily at a bright red heat; and the instrument in this form has been already completed in a skilful manner by Mr. Casella.

Of other remaining instrumental or other arrangements made or in preparation it does not seem necessary here to give any detail. The author expects to have everything complete and forwarded on to Naples before the end of 1863; and hopes to start himself for Vesuvius about the commencement of next year.

If successful there to the extent he anticipates, he may possibly try to extend his observations to some other volcanic vents, more especially to

Lipari or Etna, though the limitation of the funds placed at his disposal renders this less probable.

The author proposes to himself collaterally to examine some other dynamical and physical questions relative to the superficial phenomena of volcanic action that appear to him as yet not to have engaged sufficient attention, and is anxious to receive from vulcanologists suggestions as to such subjects for inquiry, with a view to which he has addressed himself by letter to a few of the leading minds in this branch of terrestrial physics.

Report on Observations of Luminous Meteors, 1862–63. *By a Committee, consisting of* James Glaisher, *F.R.S., of the Royal Observatory, Greenwich, Secretary to the British Meteorological Society, &c.;* Robert P. Greg, *F.G.S., &c.;* E. W. Brayley, *F.R.S., &c.; and* Alexander S. Herschel, *B.A.*

In presenting this Report upon the Luminous Meteors of the past year the Committee have much pleasure in drawing attention to the marked advance in the number of coincident observations of meteors, regarding it as a most satisfactory proof of increased vigilance on the part of observers. Thus, of one meteor, viz., that of November 27th, 1862, no less than thirty-eight accounts have been received, of which ten of the most trustworthy have been used for the determination of the path of this detonating meteor. (See Appendix No. II.) Of many other meteors also, have duplicate accounts been received.

To several meteors, of which accounts have been printed in previous Reports, satisfactory tracks have been assigned, which appear in the series of papers forming No. I. of the Appendix.

For the better determination of the heights and velocities of meteors during the August epoch, many observations were made on the 10th of August, 1863, in the S. and E. of England, and the paths and magnitudes of twenty have been calculated. (See Appendix No. V.)

Respecting the Catalogue itself no change of form has been made from that followed in preceding years, but it is enriched by the addition of several ancient observations, collected from uncommon, and generally inaccessible sources. In selection of the observations, meteors inferior to the 3rd magnitude of stars have generally been excluded from the Catalogue.

In the Appendix (following the papers bearing more immediately upon the observations contained in the Catalogue) will be found abstracts from some of the most important papers upon Meteoric Science which have appeared during the past and previous years.

A CATALOGUE OF OBSERVATION

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1761. Feb. 7	h m 8 30 p.m.	Winbourn, Dorsetshire.	......	Light enough to pick a pin from the ground.	Lasted at least 5 minutes (while leaving the carriage to run into the house).	......
1763. Apr. 29	2 48 a.m.	Observatory; Hotel Cluny, Paris.	Globe of fire; one-third diameter of moon.	Bright red ...	40 seconds falling.	12° ......
Oct. 17	7 0 p.m.	Scotland	Splendour equal to that of broad day.	......	With great velocity.	......
19	7 45 p.m.	St. Neots, Huntingdonshire, and at London.	9 in. in diameter...	......	26 seconds ...	Began immediate S. of Capella.
1769. Jan. 12	1 30 a.m.	High Holborn, Tower Hill, and at London.	......	......	......	It appeared come from t S.E.
1854. Oct.	9 11 p.m.; same hour to a minute as that of August 18, 1783.	Hurworth, Darlington, Durham.	2 × full moon at rising.	Vivid flame-colour, dark red overhead.	Lasted a few seconds.	......
1859. Aug. 20	6 40 p.m.	Amoy, China ...	Globe 4 or 5 in. in diameter to size of a man's head.	Light blue ...	Half a minute; grew swifter as it rose.	Rose a very lit height above water in the h bour; disappe ed overhead.

F LUMINOUS METEORS.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ike two pillars on the top of the house. When it disappeared, it seemed to move forward and to sink down below the roof. The interiors of the rooms were plainly visible from the outside by the diffused light.	....	....	Intensely dark night. It was also seen 6 miles from this, lasting apparently half a minute. ? Aurora.	Annual Register, 1761.
ith long tail like a rocket	....	Fell perpendicularly ...	The moon greatly diminished in brightness. Sky almost entirely overcast. Wind S.E.	M. Messier, Astronomer at Paris.
n extraordinary luminous appearance.	....	N. to S.	A similar meteor observed in France.	Annual Register, 1763.
reball	....	Course directed towards the E.	Silent. Providentially no person received any hurt.	Id.
ball of fire seen	....	....	Was attended with noise resembling thunder.	Annual Registe 1769.
ngues and coruscations all round; globular; golden - coloured neck. Tail silvery, vaporous, full of amber-coloured sparks from one side of the sky to the other; lasted a few seconds; much expanded at the point of first appearance.	....	N.E. to S.W. Appeared pretty low down and passed exactly overhead. Set below the horizon.	Tail very extraordinary. Seen also at Durham, Dundee, Sheffield (Dr. Dick).	E. Collins.
reased at first, sending off sparks at a good height like fountain jets from the main column of the light; then decreased gradually. Left a rail from the first, remaining overhead en minutes, becoming igzag.	....	Rose vertically	Many persons observed the trail of light, which was like a rent in the blue sky. The sun had not yet set.	

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
8159. Oct. 4	h m 9 5 p.m.	Roorkee, N. India	Far brighter than any star then visible in the sky.	....	Slow motion at beginning and end, quick in the middle.	Appeared at altitude 12°, due E.; passed within 5° of the zenith, and disappeared at altitude 20°, 25° S. of W.
1860. Aug. 11	....	Newhaven, Connecticut.	46 shooting-stars...	....	....	....
1861. July 16	10 10 p.m.	Vauxhall, London.	Beautiful meteor...	....	....	Descended towards the earth in a northerly direction.
24	7 10 p.m.	Lat. 22° 21′ S., Long. 3° 17′ E.	=3rd mag.*	White	1·2 second ...	From Saturn towards the horizon, along axis of the zodiacal light.
27	7 55 p.m.	Lat. 19° 44′ S., Long. 0° 18′ W.	=3rd mag.*	White	2 seconds......	From near δ Centauri to western side of Crater.
Aug. 10	About 10 p.m.	Dieppe (France)	Very brilliant shooting-star.	....	Considerable duration.	Disappeared behind hills in W.: from altitude 45°.
10	....	Newhaven, Connecticut, N. America.	95 shooting-stars...	....	....	....
10	....	Burlington, New Jersey.	289 shooting-stars..	....	....	....
15	7 0 p.m.	Lat. 6° 19′ N., Long. 25° 43′ W.	α Cygni	Slightly reddish.	1 second	α Cephei towards α Cygni.
19	7 49 p.m.	Lat. 9° 48′ N., Long. 17° 10′ W.	=1st mag.*.........	Bluish white...	2 seconds......	Through Cepheus.
20	7 35 p.m.	Lat. 10° 6′ N., Long. 28° 15′ W.	> η Ursa Major ...	White	....	α Draconis to Ursæ Majoris.
21	9 5 p.m.	Lat. 10° 46′ N., Long. 29° 28′ W.	> ♃	White	Not > 0·5 sec.	θ to η Draconis and onwards.
Sept. 25	8 30 p.m.	Lat. 50° 37′ N., Long. 0° 16′ E.	=2nd mag.*	Deep rose-red	Not > 0·25 sec.	μ Serpentis to the N.E.
25	8 32 p.m.	Ibid...............	=1st mag.*.........	White	Not > 0·5 sec.	From near χ Cephei towards S. horizon.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ar most brilliant at the centre of its course; a tail began to follow it as it rose. A fine meteor from first to last.	....	E.N.E. to W.S.W.	Gave irresistibly the impression of a body becoming luminous on entering the atmosphere.	J. Herschel.
....	....	36 or 80 per cent. emanated from a point; R. A. 48° 6′, N. Decl. 50° 57′.	....	E. C. Herrick.
ft a long and brilliant tail behind it; near the horizon the head burst and emitted a light similar to what we see when a sky-rocket bursts.	....	Its course was in a northerly direction.	....	'Illustrated London News.'
track left; no sparks...	....	Along axis of the zodiacal light.	....	T. Halis.
track left; no sparks...	....	....	....	Id.
merous shooting-stars overhead in all directions. Some lasted one or two seconds.	....	....	A fog then filled the sky; calm air.	Jas. Philp.
....	....	80 per cent. radiated from R. A. 47° 56′, N. Decl. 47° 56′.	β Camel.; R. A. 48° 6′, N. Decl. 50° 57′.	E. C. Herrick.
....	....	88 per cent. radiated from R. A. 48° 6′, N. Decl. 50° 57′.	....	V. Marsh and — Gummen.
ht train seen through wilight.	....	....	....	T. Halis.
in disappearing at same me as meteor.	....	S. to N.	....	Id.
track left; no sparks...	....	....	....	Id.
track left; no sparks...	....	....	....	Id.
track left; no sparks...	....	....	Very rapid	Id.
in	....	....	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1861. Nov. 19	h m 9 45 p.m.	London	Very surprising meteor.	Colour a fine sky-blue.	About 60° ...	....
Dec. 5	7 15 p.m.	Lat. 6° 2′ N., Long. 17° 45′ W.	=1st mag.*.........	....	1·5 sec.	From Cassiopei through Lynx.
8	8 20 p.m.	Seacombe (near Liverpool).	Half diameter of full moon. Light like the sun, casting deep shadows on all objects.	....	....	It disappeare about 40° abo the horizon, ne the three brig stars of Draco.
9	5 15 a.m.	Lat. 1° 13′ N., Long. 19° W.	=2nd mag.*	....	....	α Crucis throu β to α Ce tauri.
24	9 0 p.m.	Lat. 35° 54′ S., Long. 5°14′E.	=2nd mag.*	....	....	Greater Magella cloud to C nopus.
31	9 20 p.m.	Lat. 37° 55′ S., Long. 23° 28′ E.	=2nd mag.*	....	....	Canopus towar Achernar.
1862. Jan. 20	8 35 p.m.	Lat. 21° 30′ S., Long. 74° 20′ E.	=1st mag.*.........	White	1·5 sec.	δ Hydræ Austra to η Toucani.
Feb. 2	7 15 p.m.	Lat. 9° 55′ N., between Ceylon and Madras.	Venus	White	3 seconds......	From Monoceros 30° above t horizon.
21	8 52 p.m. G. M. T.	Cambridge Observatory.	Auroral arch	White	Endured a considerable time.	Gradually rose wards the zeni Passed over t Pole-star at 52^{m} p.m.
23	9 25 p.m.	Weston - super - Mare.	Light as strong as half-moon.	Red	....	....
Mar. 27	9 20 p.m.	Kurrachee(Bombay), India.	Exceedingly large meteor.	Blue............	2 or 3 seconds	From nearly due under Rigel the Pleiades.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ead much brighter than the tail, of a parabolic shape, about 25′ across the broadest part. Behind the head extended a tail about 5° in length and 12′ broad in the middle.	...	...	After proceeding about 60°, the meteor broke up into a great number of pieces and finally disappeared.	J. H. Davis.
...	...	...	...	T. Halis.
arge fireballs, or rather more than one. They almost immediately, suddenly, became extinct as soon as seen. A few dull red sparks remained, but these also vanished very quickly.	...	...  Meteor.  Moon.	No report heard ...	J. M^cInnes.
...	...	...	...	T. Halis.
...	...	...	...	Id.
...	...	...	...	Id.
·ain ...	...	...	...	Id.
·ft no track; no sparks...	...	N.E. to S.W. ...	...	Id.
s brightest part was towards the E.	...	Its vertex was apparently upon the magnetic meridian.	...	James Challis.
s light was comparable to a flash of lightning two miles from the spectator. Very intense.	...	...	...	Communicated by W. H. Wood.
...	...	...	...	H. Temple Humphreys.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
June 4	8 30 p.m.	Urbino, Rimini (Italy).	Fine bolide	....	....	....
5	9 20 p.m.	Lat. 52° N., Long. 89° 35′ E.	=2nd mag.*	White	1·5 second ...	From ζ Centauri to N.N.E.
14	7 15 p.m.	Lat. 1° 7′ S., Long. 85° 45′ E.	=4th mag.*	White	1 second	Through Centaurus to S.S.E.
18	9 0 p.m.	Lat. 7° 1′ S., Long. 79° 20′ E.	=2nd mag.*	Rich red	3 seconds......	From near β Triang. Aust. to δ Aræ.
July 8	6 30 p.m.	Lat. 33° 17′ S., Long. 32° 45′ E.	>1st mag.*	Arcturus	2 seconds......	λ Scorpii towards W.N.W.
19	10 15 to 11 p.m.	Prestwitch, near Manchester.	Not a single shooting-star.	....	....	....
20	7 15 p.m	Lat. 28° 48′ S., Long. 9° 54′ E.	=2nd mag.*	White	1 second	η Serpentis to S Taur. Poniat.
Aug. 4	9 45 p.m.	Euston Road, London.	Fine meteor, equal to 1st mag.*	....	5 seconds......	From star BAC 219 to do. BAC 1001.
7, 8, 9	....	Brussels, and also at Havannah.	....	....	....	....
10	8 30 to 13 p.m.	Rome; Observatory of the Capitol.	19 shooting-stars recorded.	....	....	....
10	....	Havannah and Paris.	31 and 54 shooting-stars per hour.	....	....	....
12	10 0 p.m.	Euston Road, London.	=2nd mag.*	....	4 seconds......	76 Ursæ Majoris to 3 Can. Venat.
12	10 14 p.m.	Ibid................	=2nd to 3rd mag.*	....	....	Appeared in absolute conjunction with Mizar, and vanished just under it.
12	10 49 p.m.	Ibid................	=1st mag.*.........	....	Occupied only 2 or 3 secs. in passage.	From 85 Herculis to 62 Herculis. (Approx.)
12	10 52 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1·2 second ...	From ½ (ζ Ursæ Maj., κ Bootis) to β Bootis.
12	11 1 p.m.	Flimwell, Hurstgreen (Sussex).	=1st mag.*.........	....	Rapid	From β Draconis to A Herculis.
12	11 11 p.m.	Greenwich	Bright meteor ...	White	Moved very rapidly.	Appeared from the W., and swept close below the 'Pointers' towards the horizon.
12	11 35 p.m.	Hawkhurst	=δ Ursæ Majoris...	White	0·5 second ...	Centre at κ Bootis..
12	11 41 p.m.	Flimwell, Hurstgreen (Sussex).	=1st mag.*.........	....	Rapid	From 15 Vulpeculæ to 5° below δ Aquilæ.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	Jac. Bianconi (Bologna).
rain	....	....	....	T. Halis.
o track left; no sparks...	....	....	....	Id.
eft no track; no sparks..	....	....	Slow motion	Id.
ain same colour as head	....	....	Moderately rapid. Moon 11·2 days old at noon.	Id.
....	....	....	Clear sky, fine night ...	R. P. Greg.
o track left; no sparks...	....	....	....	T. Halis.
ft a train for 3 seconds..	....	....	....	T. Crumplen and J. Townsend.
wo to three shooting-stars per hour.	....	....	Sky particularly clouded	Ad. Quetelet, Andres Poey.
small fireball. First and second magnitude shooting-stars.	....	Radiated from the head of Cepheus and cluster of Perseus.	....	Madame Scarpellini.
....	....	....	....	Andres Poey, Coulvier Gravier.
train left	....	....	....	T. Crumplen and J. Townsend.
....	....	....	....	Id.
t a slight train	....	....	Seen through clouds; part of passage quite obscured.	Id.
rkled slightly	....	....	....	A. S. Herschel.
....	....	....	....	F. Howlett.
....	Had a very long run.	....	....	W. Airy and W. Stone.
track left	5°	Towards ∂ Bootis	....	A. S. Herschel.
....	....	....	....	F. Howlett.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862.	h m					
Aug.12	11 48 p.m.	Flimwell, Hurst-green (Sussex).	=1st mag.*		Rapid	From 41 Antinoi t 55 Sagittarii.
13	0 13 a.m.	Hawkhurst	=α Aquilæ		0·6 second	Appeared 1° W of π Ursæ Ma joris.
13	0 15 a.m.	Ibid.	=α Aquilæ		1 second	From ¼ (κ α) Dra conis to near Ursæ Majoris.
13	0 30 a.m.	Ibid.	=Arcturus	Red	1 second	k to r Can. Venat
19	11 30 p.m.	Hay, S. Wales	=2nd mag.*			Halfway betwee Ursa Major an Minor. Parall to δ α Ursæ Ma joris.
23	4 0 p.m.	Georgia (North America).	Great luminosity			High up in the sk
23	9 55 p.m.	Weston - super - Mare.	Brilliant meteor; lit up the sky.			Altitude35°,S.S.W to W.
Sept.16	9 10 p.m.	Ibid.	=to Mars at his brightest.	Bright yellow	1¼ sec.; rapid	H 69 Ursæ Major to ϱ Bootis.
16	9 14 p.m.	Ibid.	=2nd mag.*	Blue	1½ sec.; slow	Fell vertically 8 below χ Dra conis.
16	9 38 p.m.	Ibid.	=2nd mag.*	Blue	2 secs.; very slow.	From υ Ursæ Ma joris to 15 Leon Minoris.
16	10 0 p.m.	Ibid.	=2nd mag.*	Blue	2½ secs.; slow	η Persei to Capel
16	10 17 p.m.	Ibid.	=1st mag.*	Dull yellow	1½ second	δ Cephei to 1 Lyncis.
18	8 54 p.m.	Ibid.	= to Venus	Bright yellow	4 secs.; very slow.	β to λ Ophiuchi
18	8 58 p.m.	Ibid	=Arcturus	Blue	2 seconds	μ to ζ Herculis
18	9 30 p.m.	Ibid.	Very bright meteor	Blue		
19	6 10 p.m.	Reigate	Large meteor in broad day, just after sunset.		Disappeared very quickly.	Fell down in th S.W.
19	10 15 p.m.	Ramsbury, near Hungerford (Wilts).				Passed among the stars Aries, Musca, an Triangula.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	F. Howlett.
No track left	6° or 7° ...	Towards θ Ursæ Majoris	....	A. S. Herschel.
Faint track 4° long, 1 sec.	....	Towards η Ursæ Majoris	....	Id.
....	....	Slight deflection in last half of course.	....	Id.
No track left	10°	δ to α Ursæ Majoris ...	....	T. W. Webb.
Like a sword. Handle silver, blade and point red, ten times as long as broad.	....	Pointed for S.W. to N.E.	....	Monticello Journal (Florida).
Left a large luminous streak.	....	Horizontal	....	W. H. Wood.
Left a narrow yellowish streak 30°, 3 seconds; η Ursæ Majoris appeared through it.	....	....	About one shooting-star every 5 minutes for $1\frac{1}{2}$ hour.	Id.
....	....	....	....	Id.
....	....	....	....	Id.
....	....	....	....	Id.
Increased in size. An adhering dull red tail 8° long.	....	....	....	Id.
Increased in size and brilliancy. From first magnitude star, became very bright, globular, and suddenly extinct.	....	....	....	Id.
slender adhering tail ...	....	....	....	Id.
....	....	....	....	Id.
ball of fire with a long tail of sparks.	....	....	A large meteor was also seen at Southampton on the same date (— Burningham, Jun.).	Thomas Burningham.
....	....	....	....	A. Butson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 19	h m 9 55 p.m.	Caen (Normandy).	Globe as large as a fist. Vividly illuminated all objects.	Globe as blue as some port-fires. Diffused light, yellow, then deep blue.	....	From the middle o α β γ Aurigæ t the middle of λ μ ψ Ursæ Majoris.
19	10 0 p.m. (+).	Manchester	Strong glare seen; from behind the observer.	....	A few seconds	Moved along in ar upward course.
19	10 12 p.m.	Chiswick	Light more intense than any single flash of lightning.	....	....	Exactly overhea when first perceived. From a little west o Vega toward the S.W.
19	10 15 p.m.	Arnside Tower...	Brilliant glare seen	Meteor bluish.	....	Moved along th sky in a N.E direction.
19	10 15 p.m.	Wellington (Somerset).	4 times ♃ or 10 times Sirius.	Body and train blue.	Not very rapid	Appeared abou 4° north o the Pleiades Moved N.W. descending fron ζ Persei to β Aurigæ.
19	10 15 p.m.	Great Malvern...	....	....	....	The track ex tended fron Capella directl towards th Pleiades, but di not reach th Pleiades.
19	10 15 p.m.	Peckham Rye, London.	....	....	....	A broken line o fire extende from the zenit to the Grea Bear.
20	5 0 a.m.	St. John's Wood, London.	As large as a small plate; very bright.	....	....	Position not ascer tained.
20–30	....	Manchester	= 8th–10th magnitude stars.	....	....	Chiefly in the N.E sky.
22	10 22 p.m.	Euston Road, London.	= to Mars	Ruddy	3 secs.; slow and uniform motion.	From 10° E. o Delphinus, an same altitud as Delphinu to 7° belov Mars.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
t first a large caudate shooting-star; tail continuous. Expanded suddenly like a bouquet, whence issued a blue globe with a tail formed into parcels. Left a train of rocket-like sparks after disappearance.	....	....	....	Eudes Deslong-champs.
rilliants were falling from it.	....	....	....	Communicated by R. P. Greg.
lobe scattered blue light; became egg-shaped, elongated itself, and disappeared without sparks. Track like a fluttering riband three or four inches broad. Yellow-orange colour near Vega, the rest beautiful blue.	....	....	....	S. Richards, Jun., communicated by T. Slater.
ke the electric light. It had a tail, and many sparks and stars.	....	....	....	Communicated by R. P. Greg
....	....	....	No report heard	James Glaisher.
....	....	....	....	Communicated by T. W. Webb
eteor not seen, but the flash only.	....	....	....	Communicated by T. Crumpton.
arge meteor	....	....	....	Id.
lescopic meteors; one, two, or even three on every fine night.	....	....	Striking frequency of them.	Jos. Baxendell.
rain 5° long	....	....	....	T. Slater.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 22	h m s 10 22 p.m.	Etchingham (Sussex).	= 1st mag.*	Red and blue, dull.	$4\frac{1}{2}$ to 5 secs...	Started very nea Delphinus; tra velled throug Pegasus and dis appeared half way between Arietis and Trianguli.
22	10 23 p.m.	Ibid.	= 4th mag.*	....	Rapid	Described a curv round the hea of Delphinus.
22	10 23 30 p.m.	Ibid.	= 4th mag.*	....	Rapid	Described a revers curve about Ca pella.
22	10 26 p.m	Euston Road, London.	= 3rd mag.*	Bluish	Rapid; 1 sec..	γ Pegasi to 22 An dromedæ.
22	10 47 p.m.	Ibid.	= 2nd mag.*	White	1 second	χ Cygni to 5° belo τ Cygni.
22	11 3 p.m.	Ibid.	= 1st mag.*	White	1 second	Crossed a point 0 48′ following and 0° 5′ S. c Mars.
22	11 31 30 p.m.	Ibid.	= 2nd or 3rd mag.*	....	2 seconds	From the Pleiad to near σ Arieti
22	About 11 48 p.m.	Ibid.	= 2nd mag.*	White	Rapid motion..	From 1° E., 6 below Mars t 8° below.
25	About 6 p.m. or very little later.	Smedmore, Kimmeridge (Dorset).	Very bright ball of light.	....	....	Presented itself a altitude 70 going towar S.E.
25	Shortly before 6 30 p.m.	Between Llangollen and Corwen.	Half size of the moon.	....	....	Appeared falli towards the W as if down up a hill, b disappeared b hind it.
25	6 28 p.m. or 6 30 p.m.	Oakley, Bishop Stortford (Essex).	A splendid meteor..	....	....	Descended in westerly dire tion.
25	6 30 p.m.	Loughton (Essex).	As large as the planet Jupiter.	Bright hues of blue and red.	10 seconds ...	From E. to N.W..

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
eteor reddish, and tail blue, or *vice versâ*. Extraordinary for its protracted course.	85°		No meteor ever seen to travel so slowly.	F. Howlett.
				Id.
				Id.
ght train	30°			T. Crumplen.
il of 2°	10°			Id.
in of 10°, lasted one second, fading gradually.				Id.
ft a train of 7°				T. Slater and J. Townsend.
t a slight train				T. Crumplen.
er attaining its greatest height, burst into about wo dozen small balls of the same light as the neteor, and retaining he same direction for or 4 seconds. Left a light smoky track behind it.				Communicated by Sir John Herschel.
y bright, and appeared o be quite close.				'The Standard,' Oct. 10, 1862.
				'The Standard,' Oct. 2, 1862.
y brilliant appearance ven in the evening ky. In the dark it ould undoubtedly ave been as fine as e large meteor of eptember 19th.			39 minutes after sunset.	

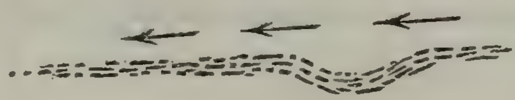
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Sept. 25	h m About 7 39 p.m.	London	Fine meteor; =1st mag.*	....	0·8 second ...	From near Polar[is] to 3° above [...] Ursæ Minoris.
25	8 32 p.m.	Brighton	Most brilliant meteor.	White, then green.	....	Descending in th[e] N.N.E.
27	Soon after 8 p.m.	Cuckfield (Essex)	Several splendid meteors.	....	....	Traversed the [...] eastern sky.
29	8 49 30 p.m.	Manchester	Decidedly > Capella; nearly = to Mars.	Bluish white..	1½ to 2 secs...	From R. A. 1h 58[m] Declination [N.] 28½° to R. A. [...] 51m, Declinati[on] N. 30°.
Oct. 3	7 35 p.m.	Vienna	One-fifth diameter of the moon.	Yellow in centre; greenish on outer edges and on tail.	2 seconds......	Altitude 34° [...] S.W.
5	8 0 p.m.	London	> Arcturus.........	....	Rapid	From near Arctur[us] to below the h[o]rizon.
7	12 30 p.m. Noon.	Mens, Fürstenberg (Mecklenburg).	Aërolite, 16 lbs. ...	....	....	....
15	9 1 p.m.	Senftenberg (near Berlin).	7′ diameter	Greenish blue, then red.	2½ seconds ...	From near Perse[us] to feet of U[rsa] Major.
15	9 14 p.m.	Ibid................	5′ diameter	Greenish blue, then red.	2 seconds......	From Pleiades [to]wards Cetus.
15	9 24 p.m.	Prague	Large fireball	Greenish	....	From altitude 1[...] to about 10° al[ti]tude at last.
15	9 30 p.m.	Senftenberg (near Berlin).	4′ diameter	....	2½ seconds ...	Polaris, past L[...] to S.W.
15	9–10 p.m.	Lake Constance, S.W. end.	= Venus	Yellowish......	3½ seconds ...	From 20° altit[ude] in E. to 30° a[lti]tude in N.E. or
16	9–10 p.m.	Rothnen-Siedel..	2 × full-moon......	Prismatic colours.	....	....
16	9–10 p.m.	Ibid................	Large fireball	....	....	....
16	9–10 p.m.	Ibid................	Large fireball	....	....	....
18	9 25 p.m.	Greenwich	= 2nd mag.*	Blue............	1 second	From α Persei [to] the Pleiades.
18	10 36 p.m.	Ibid................	= Capella............	Bluish white..	1 second	In N.; dis[ap]peared near [...] Draconis.
20	6 34 p.m.	London	A little less than Mars.	Intense white	1 second, or a little less.	From 2° W. o[f ...] Pegasi to 1° [...] of and above [...] Aquarii.
20	9 49 p.m.	Greenwich	= 2nd mag.*	Blue	1 second	From Perseus t[o ...] Andromedæ.

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
t a train of 1°	....	....	....	T. Crumplen.
nged from silvery rightness to a most eautiful green colour, t the same time emitng sparks.	....	Descended S.W. to N.N.E.	Light breeze and passing clouds.	F. E. Harrison.
or three were transndently bright and ry eccentric in their ovements, one perrming for many deees a snake-like course.	....	Serpentine course	Starlight night after an extensive distant thunder-storm.	'Kent and Sussex Advertiser,' Sept. 30.
ft no train behind it, it threw off two or ree fragments in a wnward direction at e moment of its exction.	....	Its course was undulating.	....	Jos. Baxendell.
of 30′ in length	23°	E.S.E. to W.N.W. downwards at an angle of 17°.	Described with other meteors by Dr. Haidinger.	H. Wolf.
a train for a second two.	....	Fell vertically	....	T. Crumplen.
....	....	....	Earth and sand was thrown up into a shepherd's face.	Communication by Dr. Haidinger.
....	....	....	....	T. Brorsen.
into sparks	....	....	....	Id.
train	....	Oblique path in the N.E.	....	J. Müller.
red fiery train	80°	....	....	T. Brorsen.
....	30°	Inclined slightly upwards towards Ursa Major.	....	R. P. Greg.
train	....	N.E. to S.W.	Probably October 15 ...	Id.
....	....	....	Probably October 15 ...	Id.
....	....	....	Probably October 15 ...	Id.
train	....	....	Hazy	W. C. Nash.
rain	....	E. to W.	....	Id.
tail, leaving a faint light.	10°	....	....	T. Crumplen.
train	....	....	....	W. C. Nash

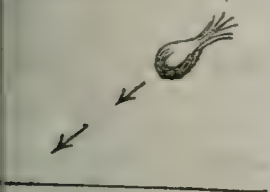
3.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Oct. 20	h m 9 52 p.m.	Greenwich	=2nd mag.*	Blue	1 second	From Cassiopeia α Pegasi.
20	11 58 p.m.	Ibid	=2nd mag.*	Blue	1 second	From direction the Pleiades t Aurigæ.
20	11 59 p.m.	Ibid	=3rd mag.*	Blue	½ second	From γ to ζ C onis.
24	10 21 p.m.	Hay (S. Wales)	=1st mag.*	Yellow	...	From 5° below Aquarii to above δ Aqua
26	7 45 p.m.	Weston-super-Mare.	A sudden brilliant light.	Colour of streak bright orange.	Meteor not more than 1 sec.; not seen.	Brightest o curved part S. by W.; altit 45°.
26	9 0 p.m. Approximate time.	Greenwich	=1st mag.*	Blue	1 second	Fell from a p a few degrees of the Pleiad
26	9 30 p.m.	Weston-super-Mare.	=Mars	Yellow	...	From altitude S.W., down the horizon below it, in S
27	6 30 p.m.	Troppau	...	...	...	Altitude 40° W.
31	8 45 p.m.	Weston-super-Mare.	=1st mag.*	Blue	1 second	From altitude in W.
Nov. 2	10 7 p.m.	Thornliebank, Glasgow.	A sudden flash illuminated every object.	Meteor white-blue.	...	Fell down fro great eleva to below horizon; a N. of W.
2	A little after 10 p.m.	Glasgow	Nearly as large as full moon.	White	...	It appeared t falling tow the horizon the N.W. o sky.
3	Evening	Prestwitch (Manchester).	Four shooting-stars in a moderate time.	...	...	...
5	6 0 p.m.	Liverpool	As large as an orange, or 5′ diameter.	Quite white	2½ seconds	In the E. from alt 30° to alt 12°.
5	6 10 p.m.	Manchester, 10 miles S.	Large fireball	...	2 seconds	From N.N.E.

…pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
………	………	………	………	W. C. Nash.
…t train ………	………	………	………	Id.
………	………	………	………	Id.
…y shooting-stars ob- …rved this evening. …wo of first magnitude …peared together.	………	………	………	T. W. Webb.
… luminosity remained …ree minutes. Disap- …ared and reappeared …veral times, the light …ctuating from right … left.	………	A little inclined to the horizon.	………	W. H. Wood.



…a train a few degrees …length.	………	Perpendicular downwards.	………	J. MacDonald.
………	………	………	Many meteors in this locality.	W. H. Wood.

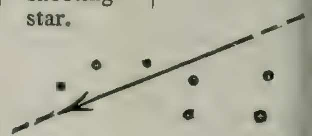


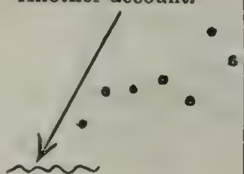
Horizon.

………	………	S. to N. ………	………	J. Schückle.
………	20° ………	Nearly vertical down …	………	W. H. Wood.
…two red sparks, the …er one brightest. …h disappeared with … meteor. No streak …	………	………	In bright moonlight …	Professor W. Thomson.
… of white flame; …n of red sparks … stars, four or five …umber. Appeared …n extraordinary sud- …ness.	………	………	Sky extremely clear at the place where the meteor appeared: bright moonshine.	Paragraph in 'Glasgow Herald,' November 4.
………	………	Radiant, ill-defined, near head of the Lynx.	Full moonlight ………	R. P. Greg.
… round; no tail or …ks.	16° or 18°..	Downwards towards the left, 70° from horizontal.	During moonlight ……	H. Gair.
…s and tail of sparks	………	………	………	R. P. Greg.

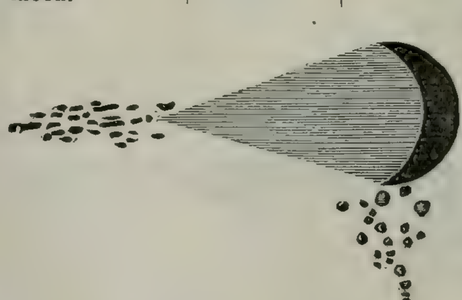
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 9	h h m 7 to 7 30 p.m.	Prestwitch, Manchester.	Not one shooting-star.	....	....	....
9	9 3 p.m.	Weston-super-Mare.	>Mars	Silvery white..	1½ second ...	From altitude 1 S.; to altitu 2°, 5° W. S.
9	10 41 p.m.	Greenwich	=2nd mag.*	Blue	Less than 1 sec.	From direction α Persei towa N.; disappea about 15° bel Polaris.
10	7 to 7 30 p.m.	Prestwitch (Manchester).	Two shooting-stars	....	....	Fell down in N.
11	7 10 p.m.	Hawkhurst	=1st mag.*	Very bright white.	Very slow motion.	From α Ursæ M joris to ι U Majoris, bu turned a p fect half ci round δ U Majoris.
11	8 45 to 9 p.m.	Weston-super-Mare.	Two or three shooting-stars; =3rd mag.*	Blue	....	From Mars wards the and from ξ H culis vertic down.
11	9 10 p.m.	Greenwich	=3rd mag.*	Blue	1 second	From direction Capella, alm to ο Ursæ joris.
11	9 28 p.m.	Ibid	=3rd mag.*	Blue	1 second	From Cepheus Draconis.
11	10 30 to 11 p.m.	Prestwitch (Manchester).	No shooting-stars seen.	....	....	....
12	6 5 p.m.	Accrington (Lancashire).	=2nd mag.*	Faint white ...	Rather slow...	Fell from Pegas
12	7 46 p.m.	Weston-super-Mare.	=to α Lyræ	Blue	2¼ seconds ...	From Mizar t Herculis.
12	8 45 p.m.	Accrington (Lancashire).	=3rd mag.*	Bright white..	Rapid; instantaneous.	About 10° al Castor.
12	9–10 p.m.	Prestwitch (Manchester).	Four shooting-stars	....	....	Two at the N horizon, in Draco. Th others eas ward, fro Cassiopeia Pleiades.
13	Until 9 p.m.	Weston-super-Mare.	No shooting-stars visible.	....	....	....
16	6 28 p.m.	Accrington (Lancashire).	=Mars	Yellow, somewhat dull.	2 or 3 seconds; tolerably quick.	From Aurig under Cap towards ades, whi it near reached.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	Sky very favourable; moon rising.	R. P. Greg.
...llar brilliancy, increas-ng; left no tail; sud-lenly vanished.	....	....	....	W. H. Wood.
....	12°	....	Fine clear night, moon shining brightly.	W. C. Nash.
...peared within one ...inute of each other; ...o other shooting-stars ...een in 30 minutes.	Long paths.	Directed apparently from Mars.	Favourable sky	R. P. Greg.
...ndy light, at last fading ... nothing.	....	Course like a fish-hook.	....	T. Humphrey.
....	....	....	....	W. H. Wood.
....	10°	....	....	W. C. Nash.
....	....	....	....	Id.
....	....	....	Bright moonlight	R. P. Greg.
....	About 10°...	Almost vertically, but inclining westwards.	....	L. E. Becker.
...s. minima of size, ...e near centre of ...urse; thin adhering ...tl.	Long path...	....	....	W. H. Wood.
....	5°..........	Fell vertically	....	L. E. Becker.
...two near the horizon ...ust have been brilliant ...ere they fell.	....	No radiant point discernible.	....	R. P. Greg.
....	....	....	Then overcast	W. H. Wood.
...e smaller, as if burn-...i itself out. Drew a ...ight train of sparks ...hind it.	....	....	....	L. E. Becker.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 16	h m 10 40 p.m.	Hampstead (London).	Bright meteor, like a globe.	Nucleus white, track greenish.	....	Appeared 2(below, and little west Mars.
16	10 48 p.m.	Weston-super-Mare.	Twice as large as Venus; light = half moon.	Bright yellow.	1½ second; very rapid.	From 4° S.E. Mars.
22	9 2 p.m.	Ibid	Resembled Mars ...	Resembled Mars.	1½ second ...	From φ Piscium τ Ceti. Pas within 3° (of Mars.
23	7 8 p.m.	Ibid	Two shooting-stars, 1st and 2nd mag.	Blue	....	Disappeared Mars.
23	8 30 p.m.	Ibid	Quarter moon's diameter.	Deep orange...	3° or 4° in 1 sec.; very slow.	Appeared 3° (o Eridani. I den from after falling or 5°.
26	6 40 p.m.	Leeds	Bright meteor	....	More slowly than any shooting-star.	.... In Ursa Majo 
26	6 48 p.m.	Peebles	Double the size of the largest planet.	....	Very rapid ...	Appeared in N Passed with g velocity across heavens to S.
26	About 7 p.m.	Selkirk (Roxburghshire).	Light like the moon	....	....	Passed overhea altitude 42°, W. from S.
26	7 45 p.m.	Melbourne (S. Australia).	Fully as large as the moon. Light quite eclipsed the moonlight.	Pale, but intensely bright hue.	....	Passed near zenith.
27	4 55 p.m.	Strasbourg	Great fireball	....	....	....
27	5 40 p.m.	Millwall, N. bank of the River Thames, opposite Greenwich Hospital.	Appeared to be as large as the full moon.	Green, yellow, blue, alternately.	....	Appeared near zenith, ar moved on inclined path wards S. hori
27	5 45 p.m.	Torquay	Apparent size of full moon.	Colour of full moon.	2 seconds......	Began and e E. of Mars. Lower th Mars.

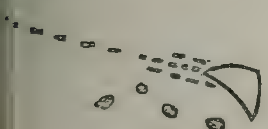
ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
eft a streak for a short time.	15° or 20°..	Downwards to the right, 30° from horizontal.	....	T. Potter; H. T. Humphreys.
ear-shaped and tailed. Burst with a shower of 1st magnitude yellow stars which fell vertically.	....	Parallel to the ecliptic, westwards.	Sky and sea calm	W. H. Wood.
ght intermittent	....	....	....	Id.
....	....	Radiated from γ Cassiopeiæ.	....	Id.
veral until 10^h p.m., in same place and direction, the last a 1st magnitude star, blue.	4° or 5° ...	Fell nearly vertical	....	Id.
ke ball of a Roman candle. Disappeared in a bank of clouds which rose up within five minutes.	....	.... Another account. 	....	John Marshall.
uminated the whole country with extraordinary brilliancy.	....	....	In 4 minutes rumbling concussions were heard for 90 seconds..	Peebles 'Advertiser' (R. Chambers).
ploded at the end of its course with a very bright ight.	....	....	A prolonged report followed the appearance in about one minute.	G. Lewis.
arly round, rather elongated. Finally disappeared behind a dark cloud.	45°	In a southerly direction	At right angles to the usual course of such visitants.	Owen's Advertiser.
train of pale-coloured ight remained for some econds.	....	N.W. to S.E.	....	Cosmos, Paris, December 5th.
low sparks thrown off hroughout the whole ourse; a train also een after meteor's disppearance for half a ninute.	....	In a S. by W. direction.	The meteor fell behind St. Alphege church, Greenwich, exhibiting that building in bold relief from surrounding objects; then suddenly disappeared, leaving all objects totally undistinguishable.	J. R. Nash.
, first mistaken for the noon; circular; then yriform, and exploded, hooting out behind it a rilliant crimson flame, ke fireworks.	28°	E. to W., sensibly horizontal.	....	W. Pengelly.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m s 5 45 p.m.	Deal	....	....	....	From near Ma passed under t moon, and bu at altitude 2 above the ho zon.
27	5 45 p.m.	Sunderland (Durham).	Brighter than Venus.	White	3 seconds......	From altitude 38° E. from S. altitude 3°, 5° from S.
27	5 45 p.m.	Springfield (Essex).	....	....	....	Passed some di tance below t moon into a lo dark cloud to t right of it.
27	5 45 p.m.	Hastings	At the end, behind houses, the light increased very brightly.	....	While a person might walk ten paces.	From about al tude 60° to abo altitude 35°.
27	5 45 p.m.	Saltford (Bath)..	Half diameter of moon.	....	Barely 3 secs...	From altitude 11 S.E., to altitu 10°, 17½° E. fro S.
27	5 45 p.m.	Broxbourne......	Magnificent meteor	Red, then blue, then red.	6 or 8 seconds	It appeared to about a mile o and 400 or 6 yards high.
27	Appeared 5 47 5 p.m.	Sandgate (near Dover).	Greatest width 0° 13′; greatest length 0° 26′. Would certainly have appeared a bright body on the surface of the moon.	Colour of meteor white, but reflected light bluish.	Not more than 4 or 5 secs.; motion slow.	Appeared at R. 23ʰ, S. Decl. 7 and disappear at R. A. 20ʰ 40 S. Decl. abo 25°.
27	5 47 5 p.m. Extinction.	Grantham	Width across the head 31′; length longitudinally 1° 17′; by comparison with the moon.	Blue	From α Ceti to end of course 8 seconds.	View commence near α Ceti passed almo across β Ceti and then im mediately abov Fomalhaut, va nishing 4° be yond this sta and about 5 above the hor zon. Droppe balls of ligh between β Ce and Fomalhaut.



...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...e a globe of phos- ...horus driving a dark- ...oloured head or bolt ...urning before it. Left a ...olden thread behind it. ...urst with a crackling ...ppearance.	....	Sloped gently down towards the W.	....	G. Brown (Deal Telegram).
...t no permanent streak, ...ut sparks only, upon a ...hort train.	....	Almost horizontal, slightly inclining downwards.	....	Rev. G. Ilyffe.
... elongated, intensely ...lue pear-shapes, raced ...losely side by side, ...receded by a flat- ...ened orb of vivid red, ...ne-eighth of the mag- ...itude of the whole, ...llowed by a stream of ...ght like that of a ...ocket.	....	....	....	Writer in 'The Standard.'
...tered sparks like a ...ece of white-hot iron ...ought out of a smith's ...e.	....	N.E. by N. to S.W. by S.	....	James Rock, Jun.
....	....	Azimuths doubtful; but altitudes correct, by house roofs, &c.	....	Francis Cotterell.
...nged from red to blue, ...d again to red, when ...disappeared.	....	....	....	Writer in 'The Morning Star.'
... shape, or like Prince ...pert's drop. A train ... red sparks left in the ...r; no coloured balls ...n to drop from the ...ad.	....	Path perpendicular to the line of the moon's cusps. Produced backwards, would have passed halfway between Mars and the moon.	Although the moon (7 days old) was extremely bright and clear, its light was lessened by the meteor.	H. P. Finlayson.
...shaped; light most ...ense in front, in a ...scent form, expanding ...asionally almost to a ...le. Cone milky white, ...sphorescent, or dim ...comparison. A train ...uddy sparks, lasting ... 3 seconds, followed ... meteor. Large blue ...s scattering yellowish ...s, which burst into ...rks, fell perpendicu- ...y from the head.	....	....	The meteor gradually increased in size, but not uniformly, an occasional decrease in size and brightness taking place. Momentary checks in the velocity each time that it discharged a shower of balls. It vanished at its maximum brightness, not bursting, but as if going behind some opaque body.	E. J. Lowe.

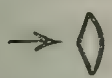
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m 5 48 p.m.	Westminster, London.	....	Many colours..	Steady motion	Moved from Parliament Houses tow the W. below moon.
27	5 49 p.m.	Euston Square (London).	Diameter equal half diameter of moon, but more brilliant than the full moon.	Very bright green.	....	First seen at I $23^h\ 40^m$, S.I 6° or 8°. appeared i view at R $22^h\ 30^m$, S.I 10°.
27	5 50 p.m.	Kensal - green (London).	Like the moon at the time.	Nucleus of a light green colour.	....	From 2° or 3 of the Pleiad about 15° or S. of the mo
27	5 50 p.m.	Clapham (near London).	Very large meteor..	Brilliant colours.	About 5 secs...	From 28° E. S. altitude to 11° W. altitude 17 18°.
27	5 50 p.m.	Near Windsor ...	Light sufficient to read by.	Rainbow colours.	....	....
27	5 50 p.m.	Liverpool	The light appeared to flash while the meteor was hidden behind houses.	Bluish white, yellow at the edges, and red at the extremity of the tail.	Moved three and a half times its own length in a second.	Altitude 8° S.E. by E. t by E.
27	5 50 p.m.	Etchingham (Sussex).	As large as the moon.	....	....	Underneath moon.
27	5 50 p.m.	Hawkhurst (Kent).	Outshone the moon; light sufficient to read by.	Blue	3 seconds......	λ Aquarii to ζ C corni.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
dy green; tail golden. Disappeared in a sparkling shower of colours.	....	....	....	H. R., writer in 'The Times.'
il like a rocket; beginning and end hidden.	....	Nearly horizontal	A serene night and sky. Moon seven days old.	A.B.Clementson.
form somewhat oval. train stretched far ehind, composed of mber- and crimson-oloured sparks. Balls ell from it, which burst nto other balls.	.... 	....	As the meteor shot forward it increased and diminished alternately in size, especially just before disappearance.	C. H. Bright.
first small, but grew ery bright, and left a rain of sparks. Disappeared without bursting.	....	Ascended somewhat ...	Positions measured by description the following evening.	Communicated by A. S. Herschel.
....	....	....	....	Writer in 'The Standard.'
ht, with a rugged ppearance, moved long the tail and rmed sparks for an istant behind it. 	About 40° ..	Inclined downwards 4° or 5° from horizontal.	Disappeared from sight behind buildings.	H. P. Horner.
owed by a train of arks.	....	E. to W., obliquely downwards.	....	E. Hussey.
streak remained, but arks followed thinly a train; beginning d end hidden by stacles. Flakes of ght were left behind low. 	....	Downwards towards the right at a considerable slope.	The light caused the observer to turn round towards the moon.	F. Young.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m 5 50 p.m.	Caen (Normandy). (Seen also at Cherbourg.)	Glare from behind only perceived.	First red, then blue.	....	Moon and haze ob[s]cured the sta[r]
27	5 53 p.m.	Weston-super-Mare.	One-third diameter of moon.	Silvery white..	4 to 5 seconds	From N.E., altit[ude] 10° to S.E. by altitude 10°.
27	5 55 p.m.	Mottingham, Chislehurst (Kent).	A ball as large as two fists; lighted up the pathway.	....	....	....
27	5 55 p.m.	Peckham Rye ...	Most beautiful meteor; large as an ordinary gas-lamp.	Beautiful blue tinge.	Did not travel at a very rapid rate.	....
27	5 55 p.m.	Mile End Road, London.	Width of head one-eighth diameter of moon.	Bright yellow, shading to rose pink and rich violet.	4 to 6 seconds	About 15° ab[ove] the horizon.
27	5 55 p.m.	Chislehurst (Kent).	As large as full moon; light sufficient to read by.	Very blue colour.	Very slow motion; visible 3 seconds.	....
27	Between 5 and 6 p.m.	Lymington (Hants).	Ball of bright blue; light like a Roman candle.	Blue, red, yellow.	....	My eyes rest[ed] on the Pleiad[es] just below th[em] issued a mass [of] light. The met[eor] cast off spa[rks] when nearing t[he] Needles. The[n] when it got o[ver] the Needles, [it va]nished away u[n]derneath the mo[on]
27	Between 5 and 6 p.m.	Etchingham (Sussex).	Splendid meteor ...	Nearly every colour.	....	....

...pearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...) turning round, a streak ...f red sparks was seen, ...ying away.	....	N.E. to S.W.	Report like distant thunder heard in one to one and a half minutes, at Caen, Colleville, Lion-sur-Mer. Described in L'Ordre et la Liberté of Caen, Le Moniteur de Calvados, and Le Moniteur Universel de Paris.	Eudes Deslongchamps and M. Toussaint.
... first small, gradually ...icreased ; halted half-...ay, with great shower ...f sparks. In E., threw ...ut a yellow tail 18° ...ng, green at junction ...ith head. Head ...ear-shaped ; burst at ...st into ten large ...eces which advanced ...bliquely towards the ...orizon.	30° of the path were seen through a cumulus cloud.	....	....	W. H. Wood.
....	....	....	....	G. M. G., writer in 'The Times.'
... a tail in its progress..	....	....	....	H. Seabrooke.
...: a riding whip, moving ...utt-end first. Burst ...ith a flash like light-...ng.	....	E.N.E. to W.S.W., exactly parallel to the horizon.	....	Writer in 'The Standard.'
...peared to divide, and ...en to burst with a ...rprising and brilliant ...fect.	....	Descended at a slight declivity.	....	C. J. C., writer in 'The Times.'
...ew off sparks in curls ...ove and below, behind ... like the scales from ... anvil. Crimson-red ... the centre, interlined ...ove with greenish ...ue, and below bright ...llow. Some sparks ...l downwards.	....	Horizontal till the last moment, when it turned upwards towards the moon.	It forced its way along as if impeded.	A. P. Falconer.
...as small when first ...en, and gradually be-...me large. It seemed ... halt midway, and a ...lendid shower of ...arks came forth of ...arly every colour.	....	E. to W.	....	F. Reeves.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m Shortly before 6 p.m.	Havre (France)..	Great fireball	....	With astonishing rapidity.	Passed over town.
27	6 0 p.m.	Newport, Isle of Wight.	....	Blue	Moderate speed.	Passed under moon, more n to the moon tl to the horizor
27	6 0 p.m.	Wrotham (Maidstone).	About equal to the moon; light not quite so bright.	Light white, like moonlight.	....	Passed under moon.
27	6 0 p.m.	Bridport (Dorset).	Rather longer than moon's diameter; twice as long as broad.	....	....	N.E. to S.] greatest hei about 20°.
27	6 0 p.m.	English Bicknor, Forest of Dean (Gloucestershire).	....	Intense blue...	....	The height ab the horizon v guessed to about 60°.
27	6 0 p.m.	Sutton Court, Abingdon.	....	....	....	....
27	6 0 p.m.	Cambridge Observatory.	Overpowered the light of the moon with intermittent flashes.	Deep blue ...	Slowly pursued its course.	Passed at ab 112° N. P. D., altitude 16°, fr S.E. to S.W.
27	6 0 p.m.	Honiton, near Exeter.	Larger than full moon.	Intensely blue	Very slow motion, 10 secs. at least.	Judging from t moon, the a tude was ab 35° from 20° of S. to 5° E. of
27	6 3 p.m.	Pendock (Worcestershire).	Half size of full moon.	Intense blue...	3 or 4 seconds	Appeared betw Pleiades a Aries. Pass under Ma and burst i mediately bel the moon.

›earance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
; a luminous track ehind it.	....	N. to S.	Seen also at Bolbec, Ivetol, and Rouen.	(Cosmos, Paris, Dec. 5th).
›earance like a Roman ındle ; a cylinder ten r twelve diameters in ngth of uniform ·ightness ; not pear- ıaped or kite-shaped. o other tail.	....	E. to W. ; straight and level course.	The moon shone brightly.	James Rock, Jun.
ticular when first seen, ıus—  isappeared as a shoot- g-star might do, va- shing not quite sud- :nly.	....	Moved downwards to- wards W.S.W., at an angle inclined 6° to the horizontal.	....	J. C. Kent.
....	....	Rose in N.E., moved horizontally, and dis- appeared in S.E.	....	Charles Walke
ı or two solitary ›arks, at first increased a stream until the ›teor was formed. ›ıe meteor increased glory and volume ıtil it vanished.	....	....	....	J. Burdor.
›udden disappearance ›s very remarkable, ›ere being apparently ı obstacle to hide it.	....	....	The same remark made at Hazely Heath, Hants, by Mr. J. Seeley.	J. Kent.
ı. flashes resembled ›mmer lightning, ıching nearly to the ıith. Dispersed ›ırks on all sides ;]t no streak ; went out ›ldenly. (ing of red and blue]ht with tail appended: ›d account).	....	....	Ring of red and blue light with a tail ap- pended (second ac- count).	H. Todd.
....	....	Almost horizontal ; somewhat depressed.	....	J. Huyshe.
llow halo and long]ıinous tail. Nume- ›ıs sparks scattered ›en it burst.	....	....	No report was heard ...	W. S. Symonds.

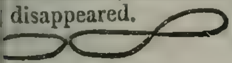
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1862. Nov. 27	h m 6 30 p.m.	Windsor	Cast shadows through a window more strong than those of the moon.	....	....	Underneath moon. Altit about 15°.
27	....	Bray (County Wicklow).	Width at head half diameter of moon, tapering to extremity of tail; four moon's diameters in length.	Blue and green	Lasted only a few seconds.	Appeared aln due E., moved rap to about S.E. at an tude of 5° or
27	....	Tunbridge	One-third diameter of moon.	....	Comparatively slow.	Appeared r Mars; descen across the sky, der the moon. appeared half from the moor the horizon.
27	8 48 p.m.	Greenwich Park..	= 1st mag.*	Blue	1 second	From direction α Draconis to Aurigæ.
Dec. 3	7 30 p.m.	Lymington	As large as the moon when full.	....	Very rapid; 10 or 12 secs.	Went S. in a curve towards Needle rocks; descended i the sea; from of Ursa Majo N.
10	About 7 p.m.	Weston-super-Mare.	Large bolide	Blue	....	From altitude 25 a little highe the E. to altit 10° S. or S.S
10 & 11	6–6½ p.m. 8–9 p.m. 10½–12 p.m.	Prestwitch (Manchester).	10 or 12 meteors = 1st mag.*	....	....	In all quarters the sky.
12	10 15 p.m.	Greenwich	= 1st mag.*.........	....	1 second	Fell down pendicularly fr a few degrees of the Pleiad
12	10 20 p.m.	Ibid	Small	....	2 seconds......	Passed from Orionis in S.W. direc for 10°.
12	10 30 p.m.	Ibid	About twice as large as Sirius.	Blue	0·5 second ...	Seemed to spr from θ U Majoris, ab 5° above it, burst at ab 2° from ι U Majoris.
13	10 26 p.m.	Ibid	= 1st mag.*, brilliant.	Blue	1 second	From α Gemino to γ Orionis.
15	6 50 p.m.	Dordogne Puycharnaud (France).	Twice Venus	White	Moved slowly.	Appeared near Pole, and mo towards the rizon.

…pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…ke into three parts like …e great meteor of …783.	………………	E. to W. ………………	………………	Writer in 'The Daily Telegraph.'
…number of sparks …ere left behind in … progress, and just …fore disappearance it …rew out the most …illiant light, blue …d green, like the ex…osion of an enormous …cket.	………………	It moved nearly horizontally.	………………	Philip Barrington.
………………	………………	………………	………………	Writer in 'The Illustrated London News.'
………………	………………	Nearly horizontal ……	………………	W. C. Nash.
…nous particles, and a …na like that of a …net followed it.	………………	………………	………………	A. P. Falconer.
………………	………………	………………	………………	Communicated by W. H. Wood.
………………	………………	Radiant point perfectly marked between Auriga and Gemini.	………………	R. P. Greg.
………………	5° or 6° …	………………	………………	J. MacDonald.
………………	10° ………	………………	………………	Id.
…cal form; left a train, …h became disunited …s before the meteor …t; the train lasted …t 0·4 sec.	40° ………	Inclined ………………	………………	C. Trapaud.
………………	………………	………………	………………	W. C. Nash.
…of white light ……	………………	S.E. to N.W. …………	During a brilliant aurora	Writer in 'Cosmos.'

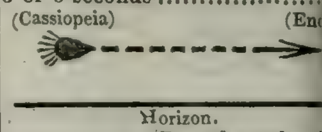
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1862. Dec. 15	h m 11 30 p.m.	Puycharnaud (Dordogne), France.	Twice Venus	White	Slow motion...	....
21	4 22 p.m.	Hull	Width quarter diameter of moon.	....	Very slow motion. Duration 30 secs.	From magnet altitude 3(true S.W.
1863. Jan. 2	9 20 to 9 40 p.m.	Edinburgh	= 2nd and 4th mag. stars.	....	....	In Taurus, (&c.
3	7 30 p.m.	Wells	Nearly as large as the moon.	....	....	Struck acros heavens fro N. to the V
6	....	Hamburg, Stettin, Magdeburg, &c.	Large meteor	....	....	....
7	6 55 p.m.	Hurst - green (Sussex).	>Mars or Venus...	Very red	....	From q r, nc π Orionis Eridani.
13	6 30 p.m.	Greenwich Park	Much>Venus ...	Bright white...	3 seconds......	From near I to immed below β Majoris.
24	8 7 p.m.	Greenwich	= Sirius	Blue............	3 seconds......	Passed perpe larly throug Pleiades.
27	The sun had set 18 min. 4 55 p.m.	Auchterarder (Perth).	Large luminous body.	Brilliant rose colour.	Descended slowly, 4 or 5 seconds.	Passed ove and proc onwards N.E.; peared beh rising grou
27	4 55 p.m.	Plean (six miles S. of Stirling).	Very brilliant meteor.	....	A few seconds	Descended Bannockbu
Feb. 7	A little after 6 p.m.	Edinburgh, five to six miles W.	Large meteor	Intensely white.	....	Appeared to scend be Currie I House and Milns, alm the horizor
7	6 30 p.m.	Glencorse Railway Station (Perth).	$1\frac{1}{2}$ feet in diameter	The sparks red	....	Appeared to 50 or 100 off. Desc from 20 yards to 3 yards fron ground.

...earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...globe of white light, ...milar to that seen at ... 50m p.m.	....	....	....	Writer in 'Cosmos.'
...esser irregular-shaped ...ody followed it; ...d a third still ...naller, upon a long ...d brilliant train of ...ght.	About 50°..	E. to W.	....	W. Lawton.
...shooting-stars	....	Radiated from Aldebaran.	....	J. C. Thomson.
...illiant meteor	....	....	....	Paragraph in 'Bristol Daily Post.'
....	....	....	....	Communication by Dr. O. Buchner.
... a slight tail and ...arks, but no lu...nous track. Burst ...th a flash, and ...nished at maximum.	....	....	....	F. Howlett.
...tly pear-shaped, with ...ght tail, which did ...t remain.	....	A nearly horizontal course.	No report heard	W. Airy.
....	12°	Perpendicularly	....	J. MacDonald.
...ast off a portion ...rhead, and two ...rks as it proceeded ...vards. One spark ... from it perpen...ularly, when it va...ned.	....	It fell nearly perpendicular, S.W. to N.E.	Bright twilight after a fine day. A stone picked up; not meteoric (J. A. Smith and M. Thomson).	James Hunter (Proceedings of the Roy. Phys. Soc. Edinb.).
... brilliant for a few ...onds, then de...ased as it de...nded like red-hot ...ilers falling from ... grate of a coal ...	....	It no doubt crossed the Ochils.	....	P. Mackenzie; communicated by R. P. Greg.
...ed red sparks, not ... stream, but at ir...ular intervals of ...ut half a second.	....	N.W. to S.E. At six miles W. of Edinburgh it appeared to fall about Ravelrigg Hill.	Seen also at Alyth and Dublin, and (?) Sydenham (London).	Edinburgh Daily Journal.
... blown ox-bladder. ... of 4 yards, and red ...ks flying from it. ...ppeared without ... apparent cause in ... air.	....	....	No higher than the telegraph posts.	David Pirrie; communicated by Sir J. Richardson.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Feb. 7	h m 6 45 p.m.	Elie (Fife)	A glimmer seen upon the sea, not intense, like sheet lightning.	Meteor intensely white, appearing blue in the ruddy sky.	Glimmer on the water 2 seconds; meteor seen ½ second.	Appeared to extinguished Arthur's Sea the peak of Pentlands; altitude a 5°, 16½° W N.
7	6 30 p.m.	Windygates, Leven (Fife), 60 yards from Windygates on the Leven-road.	Glare of light on all objects round.	....	The meteor was caught sight of for 2 or 3 secs. only.	The course from Balcorn Haugh Spin Mills; alt. 1 (From 133° to 41° 57', muth W. fro
7	6 30 p.m.	Farm of Westmains, Thirlestane. Lauder (Berwick).	Remarkably brilliant.	....	....	Appeared, alt 12½°, over W heads; d peared, alt 10°, behin hill a littl of Blainslie. (From 70° 39° 1', Azi W. of S.)
7	An hour after sunset.	East side of Loch Fine (Argyllshire).	Larger than the moon.	....	Two or three minutes.	The greatest h was 18°, a descended b a hill in neighbourh
7	6 15 p.m.	Ibid	Size of the moon: light sufficient to pick up a pin.	Bluish colour..	....	Greatest alt 25°; disapp behind a n bouring hill
8–12	9–12 p.m.	Hawkhurst (Kent).	2, 4, 4, 3, 2, 1, of 1st, 2nd, &c. mags.	11 white, 2 yellow, 3 red.	7, 5, 4 under ½ second, 1 second, and 2 secs.	Ursa, Lynx, Ge Leo.
12	7 57 p.m.	Ibid	=1st mag.*.........	White, yellow, red.	1·5 second ...	R. A. 8°, N. 58° to R.A. N. Decl. 52
12	7 57 p.m.	Weston-super-Mare.	=1st mag.*.........	....	....	R. A. 141°, N. 27° to R.A. N. Decl. 21
12–22	8–11 p.m. and 2 a.m.	Ibid	1, 3, 3, 0, 1 = to Venus, 1st mag., &c.	1 bluish white	....	In all parts ...
13	2 0 a.m.	Ibid	>Venus, very large meteor.	Bluish white...	....	From 8° N. Leonis to Ursæ Major
13	10 16 p.m.	Prestwitch (Manchester).	Very beautiful meteor, = to Venus.	White	2½ seconds ...	From R. A. 44 Decl. 66° to 12°, N. Decl
13	11 30 to 11 45 p.m.	Abercromby Place (Edinburgh).	Astonishing fireball	Body flame-coloured; tail red.	....	Rose over the of Wemyss across Quee Gardens (S. N.E.), & van over the hou Abercromby

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
appeared without iange of course, explo- on, or sparks. Broad ue streak like a ribband vice twisted, immediate- disappeared. 	....	N.W. to S.E., in a line nearly horizontal, but somewhat dipping downward.	In the blush of sunset; momentary view of disappearance only.	W. Wood.
e a rocket, not globu- ir. Emitted beautifully right colours in a raight line behind it.	....	Horizontal course	Still serene evening, without a cloud. Positions from memory.	W. M. G. Miller. Measurements communicated by Sir H. James.
own-coloured tail was en at one and the same me the whole length iat it travelled.	....	....	Positions from memory	— Edgeby; communicated by S. Whitton and Alexander Buchan. Measurements communicated by Sir H. James.
o Volans, with tail a ird or two long, but no arks seen.	....	Came from N.W., and proceeded to S.E., declining downwards.	A fine evening after a rainy day.	James Shaw; communicated by Dr. G. Rankin.
il two or three yards length, like the me- or itself. A fiery kite dragon with a long tail.	....	N.W. to S.E.	The flash like lightning was noticed in closed rooms.	— Malholland; communicated by Dr. Rankin.
een shooting-stars. iree had a sparkling pearance. No tracks t.	....	Radiant at top of Lion's head.	....	A. S. Herschel.
kling appearance; no l; ruddy before dis- pearance.	....	....	....	Id.
....	....	....	....	W. H. Wood.
left a train for a few onds; 8 shooting-stars.	....	Radiant point μ Leonis.	....	Id.
a train for a few conds.	30°	From overhead to N. by E.	....	Id.
ldid train, 2 seconds; e a bar of light 1° to broad.	....	Vertically down in N.W., as if from Dubhe.	....	R. P. Greg.
of fire, and a con- erable tail: like a ework.	....	S.W. to N.E., in an apparently almost horizontal line.	Tail and body travelled together with regular speed.	P. A. Dassauville (Proc. Royal Phys. Soc. Edinb.).

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Feb. 13	h m 11 45 p.m.	St. Andrew's (Fife).	The tail and body extended one degree.	Brilliant red...	About one minute.	Passed over centre of town.
13	12 0 p.m.	Shipston - upon-Stour (Worcester).	One-eighth sun's disc, almost dazzling.	Ruddy	5 or 6 seconds	....
13	....	Easdale (West Argyllshire).	Very splendid meteor.	....	....	Passed overheac
13–15	8–10 p.m.	Hawkhurst (Kent).	9, 3, 1, of 3rd, 4th magnitude, &c.	10, 2, 1, white, yellow, red.	6, 3, 3, 1, ½ sec., 1 sec., 2 secs., and > 2 secs.	Gemini and Ori
13–15	10 30 to 11 30 p.m.	Prestwitch (Manchester).	Fair number of shooting - stars, mostly very small.	....	....	In Ursa, Can Cepheus, &c.
14	8 56 p.m.	Hawkhurst (Kent).	Nucleus = star of 5th mag.	White	1·5 sec., 4° ...	R. A. 96°, S. D 5° to R. A. 9 S. Decl. 7°.
14	9 0 p.m.	Ibid	= 2nd mag.*	Yellow, red ...	2·4 seconds ...	R. A. 54°, N. D 1° to R. A. 6 N. Decl. 6°.
14	....	Prestwitch (Manchester).	= 4th mag.*	....	0·7 second ...	R. A. 71°, N. D 82° to R. A. 3 N. Decl. 83°.
14	....	Ibid	....	....	....	R. A. 144°, N. D 58° to R. A. 9 N. Decl. 63°.
15	A little after 6 p.m.	Folkestone	Very brilliant meteor.	Of a white colour.	Moved very slowly.	A little to the of Sirius, and a line with it.
15	6 37 p.m.	Giessen (Germany)	Large meteor	Bluish white...	3–4 seconds; very slow motion.	Fell vertically W. from 45° 10° altitude.
15	8 57 p.m.	London	= 2nd mag.*	Luminous white.	....	....
16	8 54 p.m.	Hawkhurst (Kent).	= 1½ mag.*	White, then red.	1·2 second ...	R. A. 337°, N. D 69° to R. A. 3 N. Decl. 65°.
16	11 30 p.m.	Torquay	= 3rd mag.*	Straw colour...	1 second	Appeared 5° W a point mid between Be geux and Siri
16	11 35 p.m.	Ibid	= 2nd mag.*	Bright straw colour.	Rather rapid; 2 seconds.	Passed 2° S. of Be nasch & disapp ed 10° further
16–22	8–11 p.m.	Hawkhurst (Kent).	3, 3, 4, 3, 2, of 1st and 2nd mags., &c.	11, 2, 3, white, yellow, red.	7, 3, 4, 1, ½ sec., 1 sec., 2 secs., and > 2 secs.	Camelopardalus, Auriga, &c.
17	8 9 p.m.	Ibid	= 4th, then 2nd mag. star.	White throughout.	1·6 second ...	R. A. 74°, N. D 36° to R. A. 9 N. Decl. 25°.
17	8 49 p.m.	Ibid	= 1½ mag.*	White, then red.	1·5 second ...	R. A. 114°, N. D 29° to R. A. 1 N. Decl. 19°.



…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…nificent meteor. Of a …illiant red appearance, …ith very bright flame-…ke flashes in front.	………………	Passed over the centre of the town, taking a N.E. direction.	………………	'St. Andrew's Gazette,' Feb. 1863.
…dy dazzling appear-…nce, the hinder part …eaking into sparks.	20° ………	Eastward, horizontal, below Cassiopeia.	………………	James Gorle.
………………	………………	………………	………………	J. White; communicated by A. Buchan.
…teen shooting-stars; 5 … tails or a sparkling …earance; no tracks left.	5° to 30° …	Radiant, λ Leonis ……	On Feb. 15th, 9^h 20^m p.m. to 9^h 50^m p.m., 8 appeared in 30 min.	A. S. Herschel.
………………	………………	Presented a good radiant point in Leo Minor.	On the 14th, 6 appeared in 30 minutes.	R. P. Greg.
…ounded by a brushy … nebulous envelope ½° …de.	………………	………………	Good view, clear sky …	A. S. Herschel.
…ast tailed; red; long …d arrow-like.	………………	Almost horizontal, N.W. to S.E.	Remarkable appearance	Id.
…ed in the quadrant of …ircle round Polaris.	………………	………………	………………	R. P. Greg.
… slightly undulating…	………………	………………	………………	Id.
………………	………………	Moved towards IV. of a watchface held with XII. vertical.	………………	Mrs. McLeod.
…enly disappeared……	35° ………	Fell vertically E. to W..	No detonation ………	Communicated by Dr. O. Buchner.
…t train ………………	………………	………………	………………	T. Crumplen.
…t tailed; nucleus and …l arrow-like, dull red.	………………	………………	………………	A. S. Herschel.
…ared to die out ……	One - third Betelgeux to Sirius.	Horizontal, W. to E. …	………………	W. Pengelly.
…peared suddenly……	Betelgeux to Sirius.	Sensibly horizontal, S.E. to N.W.	………………	Id.
…n shooting - stars; … were tailed; one … a track for 1 sec.	10° to 35°..	Two radiants, Leo's head and Capella.	………………	A. S. Herschel.
…peared for 2°; reap-…red 2nd magnitude, …ving a track 6°, one …ond, white.	………………	………………	………………	Id.
…t tailed; nucleus and … arrow-like, dull red.	………………	………………	………………	Id.

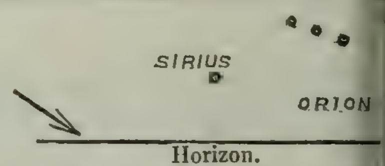
Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1863. Feb. 20	h m 6 25 p.m.	Giessen (Germany).	Large meteor	Train greenish	....	In the S.E. ...
20	10 35 p.m.	Hawkhurst (Kent).	=1st mag.*	White	2·2 seconds ...	R. A. 83°, N.] 20° to R. A. N. Decl. 23° W., altitude
22	10 45 p.m.	Eccles, near Manchester.	....	....	....	Fell due S., about the alt of Canis Maj
Mar. 4	6 36 p.m.	Hawkhurst (Kent).	Half diameter of moon. Like the crown of a hat.	Yellow, then white, at last red.	3 to 4 seconds	Came nearly the Pole, or the end of Great Bear's Passed behi tree, alt. 9°, 4 of E., and down to th point of the rizon. 2ndly, among trees 18° N. of altitude 3½° 14° N. of altitude 2°, towards 9° E., upon th rizon.
4	6 36 p.m.	Prestwitch (Manchester).	Brilliant meteor ...	White, then red.	2½ seconds ...	Appeared alt 15°, 5° S. Disappeared titude 3° o E.S.E., ½ E.
4	6 30 to 6 45 p.m.	Accounts from 12 Coastguard Stations, Hastings.	Equal to a 12-lb. rocket. Flash observed when the meteor was hidden by cliffs.	Silvery white, then bright blue; fiery red before it disappeared.	3 to 5 seconds	Appeared N. by W. Burs tween Galle and Dung Point; or on buildings, as from Bexl Station flag Almost tou the water b it disappear burst.
4	6 30 p.m.	Hereford	Meteor like a rocket	....	Descended gradually.	Rather low in t It reached horizon, or lost in the of the horiz
4	6 32 p.m.	Bredon (Tewkesbury).	Brilliant as the moon.	In colour like the moon.	....	....
4	6 4 p.m.	Bracondale (Norwich).	Splendid meteor ...	Brilliant blue, changing to red.	5 or 6 seconds at least.	Across the sky, to S.E.
4	6 1 p.m.	London	....	....	....	Near Cor Caro

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…eak train of greenish …lour. Disappeared …ddenly.	....	Downwards towards the right; 40° from horizontal.	No detonation............	Communicated by Dr. O. Buchner.
…orm motion and ap…earance. No tail or …arks.	....	S. to N.; horizontal ...	....	A. S. Herschel.
....	....	....	....	T. Mackereth.
…l at first and like a …ndle-flame. Then …panded to a brilliant …ite ball near the …oon, sparks flying from …derneath, like a horn. …sappeared gradually …low the horizon as a …d ball the size of a hat, …thout sparks.	....	Came nearly from the Pole, or from the end of the Great Bear's tail; or from altitude 14½°, 12° E. from N. It was descending at a slope of 23½° to the horizon when it disappeared.	....	J. Birch; T. Humphrey; F. Reeves; J. Jeffrey. Communicated by A. S. Herschel.
…a train of sparks	....	Downwards towards the right, 50° from horizontal.	....	R. P. Greg.
…st globular; at last … a rainbow-coloured …eam behind it (like a …net's) consisting of …st brilliant light. No …rks from it at disap…rance, for it did not …st, but was lost sight …	....	About W.N.W. to E.S.E., in a very low transit.	Full moon; no clouds, but a hazy atmosphere.	Communicated by F. W. Gough, R.N.
…teor resembling a …et, leaving a long …, with sparks, …nd it.	....	Descended gradually ...	....	Communication by T. W. Webb.
....	....	N. to S., in a slanting direction towards the earth.	....	....
…ndid meteor	....	....	Full moon effaced the stars, but meteor eclipsed the moon.	Communicated by J. Glaisher.
....	....	....	....	Communicated by T. Crumplen.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Mar. 4	h m 7 0 p.m.	Erbach (Odenwald).	Very brilliant meteor.	....	Slowly disappeared.	N.E. to N.W., sl[o] disappeared [...] the horizon.
4	About 7 30 p.m.	Shoreham (Brighton).	Brilliant meteor ...	Conspicuous colours were red, white, and blue.	Travelled at great speed.	Passed over [...] cing College.
4	....	Westphalia (many places).	Very brilliant meteor.	....	....	In the W. ....
7	7 35 p.m.	Weston-super-Mare.	=1st mag.*	Dull red	7 secs.; slow motion.	R.A. 155°, N.I[...] 32° to R.A. 2[...] N. Decl. 62°.
7–17	7 30 to 11 30 p.m.	Ibid	9, 0, 2, 3, 1, of 1st mag., 2nd mag., &c.	7, 1, 2, 5, blue, yellow, red, misty.	7, 4, 3, 1, < ½ sec., < 1 sec., < 2 secs., & = 7 secs.	In all parts of sky.
9	10–11 p.m.	Hawkhurst (Kent).	No shooting-stars above 4th mag.	....	....	....
10	10 30 p.m.	Weston-super-Mare.	Remarkable meteor	....	....	In the N. ....
11	9 48 p.m.	Prestwitch (Manchester).	=to Sirius	White	0·75 second ...	R. A. 149°, S. I[...] 29° to R. A. 1[...] S. Decl. 32°, onwards.
11	11 3 p.m.	Ibid	=1st mag.*	Reddish white	1 second	R. A. 161°, [...] Decl. 75° to 348°, N. I[...] 78°.
11–17	8 30 to 12 0 p.m.	Ibid	3, 8, 9, 8, 1, of 1st mag., 2nd mag., &c.	10 white; the rest reddish white, or dull.	12, 12, 2, < ½ sec., < 1 sec., < 2 secs.	In Lynx, Ge[...] Leo, Hydr[...] Virgo.
12	8 33 p.m.	Hawkhurst (Kent).	=1st mag.*	White	1·2 sec.; fast..	R. A. 120°, N. I[...] 24° to R. A. 1[...] N. Decl. 4°, [...] tude 58° to [...] tude 20°.
12	8 53 p.m.	Ibid	=5th mag.*	White	0·7 sec.; very slow.	Centre β Canc[...]
12	9 11 p.m.	Ibid	=2nd mag.*, then =4th mag.*	White, then red.	1·5 second ...	R. A. 186°, N. I[...] 59° to R. A. [...] N. Decl. 68°
13	8 20 p.m.	Ibid	=2nd mag.*	Saffron.........	0·3 second ...	In Camelopar[...]
13	10 17 p.m.	Prestwitch (Manchester).	=Sirius	White	2·3 seconds ...	R. A. 124°, N. I[...] 14° to R. A. [...] N. Decl. 26°, [...] tude about 5[...]
13	10 27 p.m.	Weston-super-Mare.	=Venus	Yellow	3 seconds......	R.A. 158°, N. I[...] 2° to R. A. 1[...] S. Decl. 6°.

…arance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…coloured train ………	………………	………………………………	………………………………	Communicated by Dr. O. Buchner.
………………………………	………………	N.W. to S.E., towards the sea.	………………………………	'Sussex Advertiser,' Mar. 12.
… train ………………	………………	N. to S. ………………	………………………………	Communicated by Dr. O. Buchner.
… ruddy tail 6° …g, curled off until … nucleus was ex…usted.	60° ………	Last half of course snake-like and curvilinear.	Remarkable object ……	W. H. Wood.
…ll fireball, 2 conical…ed meteors, &c. = …shooting-stars.	5° to 60°…	One with snake-like course.	No radiant point distinguishable.	Id.
………………………………	………………	………………………………	No moon; hazy sky …	A. S. Herschel.
…bled a dumb-bell …	………………	………………………………	………………………………	C. Pooley.
…t a disc; no track …	………………	………………………………	………………………………	R. P. Greg.
…ntary train…………	………………	………………………………	………………………………	Id.
…rushy or misty, and … left a track; one … a long track and …ks.	2° to 40°…	Radiant point not discernible. Perhaps a radiant point in Virgo.	………………………………	Id.
…in or sparks ………	38° ………	Vertically, N. to S. ……	………………………………	A. S. Herschel.
…al. A cluster ½° …. Total=5th mag.	4° or 5° …	Horizontal, E. to W. …	Good view; clear sky…	Id.
…cted termination; … mag.; orange and … red. No sparks or …	………………	………………………………	………………………………	Id.
…n or sparks ………	5° ………	From Leo Minor ………	The only shooting-star from 8–9 p.m.; sky partly cloudy.	Id.
… train and small …s.	………………	Horizontal, S.S.W. to N.N.E.	………………………………	R. P. Greg.
…ed from 2nd mag…le star. Vanished at …mum brightness; …w bright yellow tail … sparks, red at junc… with the nucleus.	………………	………………………………	A fine object …………	W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Mar. 15	h m 7 45 to 8 15 p.m.	Hawkhurst (Kent).	No shooting-stars above 5th mag.	....	....	....
17	12 30 to 1 30 a.m.	Ibid	=4th and 5th mag. stars.	White and yellow.	Rapid	In all parts ....
17	1 12 a.m.	Ibid	=Sirius	White	1·2 second ...	R. A. 189°, S. D 9° to R. A. 1 S. Decl. 17°, tude 12° in E.
17	8 58 p.m.	Weston-super-Mare.	>1st mag.*	Blue, then white.	$1\frac{1}{2}$ second ...	R. A. 87°, N. D 18° to R. A. S. Decl. 8°.
17	10 30 p.m.	Hawkhurst (Kent).	=♃	White	0·7 second ...	R. A. 171°, N. D 62° to R. A. 1 N. Decl. 70° overhead.
17	11–12 p.m.	Prestwitch (Manchester).	No shooting-stars seen.	....	....	....
17–21	8–11 p.m.	Hawkhurst (Kent).	=3rd to 5th mag. stars.	White and saffron.	Rapid	In all parts ....
18	11 9 p.m.	London	=3rd mag.*, then =1st mag.*	White, then blue.	1 second	In R. A. 208°·2, Decl. 33°·4.
21	8 4 p.m.	Ibid	=7th mag.*	Ruddy	0·1 second ...	Crossed the ne of Orion.
23	8 29 p.m.	Wilmslow (Manchester).	Very brilliant meteor.	....	2 seconds......	....



Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
23	8 29 p.m.	London	At maximum equal to Sirius.	White, changed to intense blue.	1·5 second (?)	R. A. 95°, S. D 8° to R. A. S. Decl. 19½
23	8 30 p.m.	Weston-super-Mare.	=♃ (?)	White (?)......	2 seconds......	R. A. 160°, S. D 14° to R. A. 1 (±), S. Decl (±).
23	8 30 p.m.	Hay, S. Wales...	About = ♃	Pale bluish green.	Rather a slow motion.	R. A. 141°, Decl. 10° to 117°, S. D 25°. Path ne reached to horizon.
23	8 30 p.m.	Portsmouth ..	Commencement faint; reached full size and brilliancy after half its course.	Brilliant pale yellow, or else red with green periphery.	....	Passed 3° or 4 of the belt Orion.

…arance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	Sky somewhat hazy ; then overcast suddenly without wind.	A. S. Herschel.
hooting-stars (one= …ius) ; no tracks left.	....	No radiant point discernible.	....	Id.
…rain or sparks. Dis… …peared abruptly at …eatest brightness.	....		....	Id.
…ged from blue to …ite ; with bluish …oky conical tail 3° …g.	....	....	....	W. H. Wood.
…test at middle of …h. Brushy ; no tail …sparks.	10°	W.S.W. to E.N.E.	....	A. S. Herschel.
....	....	....	Fine sky	R. P. Greg.
…hooting-stars. No …k left.	....	No radiant point discernible.	....	A. S. Herschel.
…ly increased, and …idly diminished.	No path ...	Stationary	A curious object	T. Crumplen.
…ke, with power of 80 …neters. Faint gaseous …it upon the track.	....	N. to S.	Seen in telescope ; aperture 15 in. ; field 0° 34′.	Id.
…t-like. Burned low … a rocket.	....	About 30° from horizontal course.	No meteor ever seen to go so near to the horizon.	A. Greg.
…haped, with nebu… … envelope surround… …the nucleus. Left a … sparks and a train …$1\frac{1}{2}$° for a few mo…ts.	....	Almost vertically down ; a little left to right.	....	T. Crumplen.
…sed and disappeared … a flash, among …ls.	....	....	Seen through mist ; misty and cloudy.	W. H. Wood.
…eased very much at …iddle of its course. …rain seen.	....	....	Observed through trees.	T. W. Webb.
… burst into a large …mall ball. 	....	Downwards towards the right ; 10° or 12° from vertical.	....	Communicated by J. P. Maclear, R.N.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Mar. 23	h m s 8 30 p.m.	Brading, Isle of Wight.	Very large meteor; gave more light than the young moon.	White	Lasted but a short time.	Fell a very li way east Sirius; vanis suddenly, 8° low Sirius, 10° above horizon.
24	10 19 p.m.	Weston-super-Mare.	=1st mag.*.........	Red and white	¾ second	R.A. 188°, N. D 1° to R.A. 1; S. Decl. 16°.
25	12 0 p.m.	Hawkhurst (Kent).	=♃, then 5×♃, then =2nd mag.*	White, then blue, then red.	3·3 seconds ...	From ½ (h υ) U Majoris to Ursæ Minc Overhead, gc E.; collapsedr N Camelop dali. A Ursæ noris appeare be the met become stati ary.
Apr. 1–30	....	Weston-super-Mare.	Many very bright...	....	....	Radiated from pheus, Cas peia, and Dra
12	10 14 p.m.	Hawkhurst (Kent).	Brighter than Capella.	Yellow, then orange.	1·9 second ...	From ½ (κ Ursæ M joris, n Lyncis 1° S. of δ Au gæ. Altitude N.W.
12	10 55 p.m.	Ibid	=2½ mag.*	Yellow	0·8 second ...	From ½ (P Q) melopardali K Camelopard
13	8 15 p.m.	Sheffield	The brightest meteor ever seen.	White, at last red.	Lasted 20 secs. 60°.	Fell down in N.E., from the of the Great Be
13	10 55 p.m.	Hawkhurst (Kent).	=3rd mag.*	Orange.........	1·2 second ...	From m Custodis 2° above ε C siopeiæ.
16	10 15 p.m.	Ibid	=3rd mag.*	White	0·5 second ...	From ½ (P N) melopardali star BAC 232
16	10 43 p.m.	Ibid	=3rd mag.*	White	0·5 second ...	From BC Came pardali ⅔ towa λ Persei.
16	10 45 p.m.	Ibid	=3rd mag.*	Yellow, then orange.	1·8 second ...	From ½ (θ Auri θ Gemini) ⅔ wards α Aurig
16	11 5 p.m.	Ibid	=to Jupiter	White	0·5 second ...	From ½ (γ κ) H culis to π S pentis.
17	10 36 p.m.	Ibid	=3½ mag.*	White	0·8 second ...	ϵ Ursæ Minoris T. Cephei.
18	9 26 30 p.m.	Euston Square, London.	Not quite so bright as Saturn.	Of a ruddy tinge.	....	From 5° under C Caroli to n Saturn in t line joining t two.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...did not burst or col-...apse to a star, but ...anished.	....	....	Moon 3·8 days old; clear sky; good view.	W. Airy.
...ionary for ½ second ...st before disappear-...nce.	....	Vertical	....	W. H. Wood.
...ge white shooting-star, ...w to a blue ball in 10°, ...te circular: 10° further ...three red sparks, and ...mediately collapsed to ...d star, which continued .... Collapse sudden from ...atest size (5′ or 6′), to ...mall red star of 2nd ...g., which advanced with ...form velocity 10°. No ... or streak.	....	....	Full moon; clear sky. The three sparks remained on the line of flight, = to 2nd mag. stars, close together, and disappeared at the same time with the nucleus.	A. S. Herschel.
...ting-stars observed ...ring the month.	....	A well-defined radiant point at β Libræ.	....	W. H. Wood.
...nished to 4th mag. ...r, changing to orange ...last third. No sparks; ... track left.	....	Going to N.W.	A very striking object...	A. S. Herschel.
...test in the middle; ... train or sparks left.	....	....	....	Id.
...a fireball, leaving a ...n of sparks.	....	....	....	A. H. Winter, in 'Manchester Guardian,' Ap. 14.
...rain or sparks; ...ghtest in the middle.	....	....	....	A. S. Herschel.
...rain or sparks; ...ghtest in the middle.	....	....	....	Id.
...est at middle; no ...a or sparks.	....	S.W. to N.E.	Altitude 20° N.W.	Id.
...est at first, then ...w-like 1° long, with ...ge tail. No track ...	....	....	....	Id.
...dden flash, seen ...ugh clouds.	....	....	Position uncertain	Id.
...in or sparks	....	....	....	Id.
...ped by a nebulous ..., perhaps auroral. ... a long tail, which ...ured 0·5 second.	....	....	The sky was covered with auroral haze.	T. Crumplen.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Apr. 18	h m s 10 29 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0·5 second ...	From T. Cephe halfway to Tarandi.
18	10 59 p.m.	Ibid	=1½ mag.*, then 2½ mag.*	White, yellow, orange.	2·2 seconds ...	From ψ Cephe across α Cassic peiæ and 1½ beyond.
18	11 0 p.m.	Ibid	=3rd mag.*	Yellow	1 second	Appeared at e Custodis.
19	10 35 p.m.	Ibid	=3rd mag.*	Yellow, then white.	1·5 second ...	From star BA(1001, ⅔ toward ζ Aurigæ.
20	0 4 a.m.	Ibid	=1½ mag.*	Yellow, then orange.	1·3 second ...	κ Ophiuchi to Herculis.
20	9 12 p.m.	London	Small meteor	Colour faint red.	About 0·6 sec.	About 15° S.W. o Polaris.
20	10 23 p.m.	Hawkhurst (Kent).	=2½ mag.*	White	0·8 second ...	Appeared at ε Per sei; disappearec almost at th horizon.
20	11 20 p.m.	Euston Square, London.	A fine rocket-like meteor, = 1st mag.*	Rather ruddy..	3 seconds......	From near ν Booti to ½ (μ ι) Vir-ginis.
20	11–12 p.m.	Castle New, Strathdon.	Several falling stars	....	....	....
22	....	Prestwitch (Manchester).	Small meteors......	....	....	....
22	10 12 30	Hawkhurst (Kent).	=1½ mag.*	....	0·3 second ...	From 25° E. of S. altitude 45°, tc 15° E. of S., alti-tude 50°.
22	10 58 30 p.m.	London	=3rd mag.*	Yellow	1·9 second ...	From δ Coronæ tc η Herculis.
22	10 59 p.m.	Ibid	=4th mag.*	White	0·8 second ...	From μ Bootis tc ζ Herculis.
22	11 0 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	0·2 second ...	From 60° E. of N. altitude 60°, tc 20° E. of N. altitude 40°.
22	11–12 p.m.	London	No shooting-stars visible.	....	....	....
22	11 11 p.m.	Ibid	=2½ mag.*	White	0·7 second ...	From ι Canum Ve-nat. to κ Bootis.
22	11 12 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	0·5 second ...	From 45° W. of N., altitude 65°, to 10° W. of N., altitude 55°.

›pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
ightest at middle of its path. No train or sparks.	....	....	....	A. S. Herschel.
ightest at first, becoming smaller at last and ruddy.	....	....	....	Id.
›e path had a double lexure at the middle.	10°	Directed from ι Cephei.	....	Id.
‹indled, white, after extinction, for last ourth part of course, vhich was bent upvards.	....	....	....	Id.
›t a bright yellow streak pr 0·5 second.	....	....	Fine meteor; rose directly upwards.	Id.
....	....	....	....	H. Davis.
›ghtest at middle of the ›ath. No sparks or ›ain.	8° or 10°...	Directed from Polaris...	Very low in the N.W....	A. S. Herschel.
›n of 10°, fading in second. Did not ›pear to explode, ›t faded very sud›enly.	....	....	....	T. Crumplen.
....	....	Directed from Corona...	Falling stars very plentiful this night.	Alex. Walker.
....	....	Radiant in Corona	Five shooting-stars seen during the month.	R. P. Greg.
....	....	Moved upwards, rising..	....	J. F. W. Herschel.
›rain or sparks	....	....	....	A. S. Herschel.
›rain or sparks	....	....	....	Id.
....	....	.... 	No meteor appeared from $10^h\ 12^m\ 30^s$ p.m. to 11^h p.m.	J.F.W. Herschel.
....	....	....	Perfectly clear sky; no moon.	H. C. Macleod.
›n partially seen. Di›ctly overhead.	....	Directed from Cor Caroli.	Sky perfectly clear; no more meteors until $12^h\ 10^m$ p.m., when desisted.	A. S. Herschel.
....	....	.... 	Not the smallest meteor after this until $12^h\ 1^m\ 15^s$ p.m., when desisted. Sky very clear.	J.F.W. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. May 4	h m 11 30 p.m.	Brighton Marine Parade.	Completely eclipsed the strong light of the moon.	Variegated, kaleidoscopic colours.	A few seconds	The same altit as the moon line. The bre of the hands between the and the me would cover distance betv it and the m
5	About 10 p.m.	Prestwitch (Manchester).	......	......	......	From η Dracon b Can. Venat
5	About 10 p.m.	Ibid	......	......	......	From π to γ pentis.
9	About 10 p.m.	Ibid	......	......	......	From κ to δ C and 6° beyo
13	11 6 p.m.	Hawkhurst (Kent).	=5th mag.*	White	0·5 second ...	On the line betw τ and ρ Herc
13	11 9 p.m.	Ibid	=3rd mag.*	Orange	1·2 second ...	From γ Bootis to γ Ursæ Maj
13	11 27 p.m.	Ibid	=2½ mag.*	Yellow	0·7 sec d	On the line betw S Bootis a Ursæ Maj centre half
13	11 45 p.m.	Ibid	=3rd mag.*	White	1 second	ζ Lyræ to δ Cy
15	10 40 p.m.	Ibid	=3rd mag.*	White	0·6 second ...	From ½ (δ, ϵ) Majoris to γ Majoris.
15	11 55 p.m.	Ibid	=3rd mag.* (+)...	White, then yellow.	1·6 second ...	From ϵ Bootis way to τ Virg
23	9 10 p.m.	Greenwich	=1st mag.*	Blue	1 second	Fell from a degrees b the moon.
23	9 20 p.m.	Ibid	Small	......	3 seconds......	Fell from the ze towards the
23	10 0 p.m.	Ibid	=2nd mag.*	White	3 seconds......	From altitude due N. to alti 30° N.E.
23	10 10 p.m.	Ibid	=1st mag.*	Blue	2 seconds......	Fell from the ze towards the
23	10 30 p.m.	Ibid	=3rd mag.*	Blue	1 second	From altitude W. to alti 15° W.
23	10 45 p.m.	Ibid	Small	Bluish white...	1 second	Appeared in S.E., about above the rizon, and d peared in th at a slightly elevation.
24	8 37 p.m.	Esplanade, Southsea.	Size of the half moon when at its greatest altitude.	Yellowish white.	From first appearance until bursting 3 secs.	1° 2′ W. from altitude 30° a the horizon (nearly).
24	10 33 p.m.	Hawkhurst (Kent).	=3½ mag.*	White	0·5 second ...	From η Dra towards η Minoris.

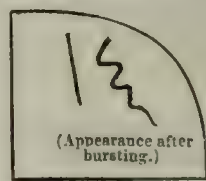
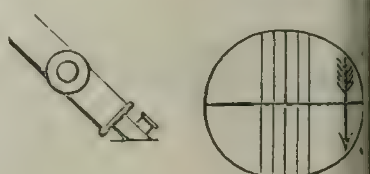
ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
small spot of light with rays rapidly revolving, eccentric, and kaleidoscopic. Dropped brilliant coloured balls of fire, and after one brilliant coruscation, suddenly faded.	....	Perfectly stationary ...	An imposing spectacle ..	H. Mullens.
....	30° or 40°..	....	....	R. P. Greg.
....	3° or 4° ...	....	....	Id.
....	15°	....	....	Id.
tail or sparks............	6°...........	....	Path not straight	A. S. Herschel.
ght once interrupted; no tail or sparks.	....	....	....	Id.
nished at maximum brightness.	6°...........	....	....	Id.
tail or sparks; brightest at last.	....	....	....	Id.
tail or sparks...........	....	....	No other shooting-star until 11^h 40^m p.m.	Id.
train or sparks	....	....	....	Id.
....	....	Perpendicular	....	J. MacDonald.
....	....	....	....	Id.
light train	20°	Inclined	....	Id.
....	....	....	....	Id.
ne	15°	Perpendicular	....	Id.
ne	....	Horizontal	....	Id.
meteor was like the oon peeping through crevice of the ouds. Pear-shaped; her particulars obured by clouds.	....	Stationary	The whole sky was obscured by clouds.	W. Penn.
ail or sparks............	10°	....	....	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. May 24	h m s 10 41 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	0·5 second ...	On a line fr ζ Draconis Mizar; cen halfway.
24	11 10 p.m.	Ibid	=2½ mag.*	White	1·2 second ...	From ½ (μ, ν) t Draconis.
24	11 18 p.m.	Ibid	=2nd mag.*, then 3rd, 4th mag.	Yellow, then orange.	3·2 seconds ...	From R. A. 25 S. Decl. 5° R. A. 271°, Decl. −6°.
25	10 20 p.m.	Greenwich	=2nd mag.*	....	5 seconds......	Fell from a degrees bel Jupiter towa the horizon.
26	9 58 p.m.	Ibid	=Jupiter	Body blue, tail red.	6 seconds......	From the zeni moved slo for 20° towa the W.
29	1 12 a.m.	Hawkhurst (Kent).	=2nd mag.*	Saffron.........	1 second	Centre γ Sagitt
June 1	9 25 p.m.	Ibid	=2nd mag.*	White	1·2 second ...	τ Herculis to Caroli.
1	11 8 p.m.	Ibid	=2½ mag.*	....	1 second	λ to ½ (μ, ν) O uchi.
1	11 12 30 p.m.	Ibid	=2nd mag.*	....	1·3 second ...	Disappeared 2 above the mo
1	11 14 p.m.	Ibid	=3rd mag.*	Yellowish......	1·2 second ...	Appeared near Scorpii.
1	11 30 p.m.	Weston - super - Mare.	Larger than Sirius..	Coloured red...	Motion very slow, 4 secs.	From R. A. 2 N. Decl. 22 R. A. 224°, Decl. 5°.
6	10 0 p.m.	Blackheath	Four times as large as Jupiter.	Blue	1½ second ...	Fell from zen almost per dicularly to horizon.
8	10 42 p.m.	Hawkhurst (Kent).	Diminishing, 2nd, 3rd, 4th mag.*.	Yellow, then red.	3·5 seconds ...	From the barl Sagitta, betw β and ε Delp to a line thro λ, η Aquilæ.
20	11 55 p.m.	Weston - super - Mare.	=1st mag.*.........	Blue	½ second	From R. A. 3 N. Decl. 30 R. A. 315°, Decl. 20°.
July 11	11 18 p.m.	Hawkhurst (Kent).	= to Altair, then 3rd mag.*.	White, then yellow or orange.	3·1 seconds ...	β Aquarii to below η Aqu
11	11 27 p.m.	Ibid	= to Altair	White	1·3 second ...	From 1° abo Capricorni 1° below Aquarii.
11	11 35 p.m.	Ibid	=3rd mag.*	White	0·9 second ...	From ½ (τ, ν) C to β Lyræ.
11	11 39 p.m.	Ibid	=3rd mag.*	White	0·8 second ...	Appeared at ½ (Pegasi.
11	11 45 p.m.	Ibid	=3rd mag.*	Yellowish......	0·9 second ...	γ Aquilæ to above θ Aqu

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
tail or sparks............	....	....	....	A. S. Herschel.
ail or sparks............	....	....	....	Id.
ppeared gradually. range tail of sparks 1° ng, in last quarter of e flight.	....	....	....	Id.
ght train	....	....	....	J. MacDonald.
ain of red sparks re-ained 2 seconds after e meteor disappeared.	20°	....	....	Id.
sparks and a train mained 1 second.	....	Horizontal; N.E. to S.W.	....	A. S. Herschel.
rain or sparks	....	....	....	Id.
rain or sparks	....	....	....	Id.
rain or sparks	8°............	Downwards, right to left, 20° from vertical.	....	Id.
il. Sparkled	5°............	Moved horizontally towards the W.	....	Id.
linear and irregular tion in last 8 or 10 grees. Faint tail.	....	....	....	W. H. Wood.
sh sparks at disap-rance.	....	....	Cloudy. Position, &c. of meteor not exactly noted.	W. C. Nash.
il or sparks; ruddy dull in last half of course.	....	....	Sky partly overcast; showery.	A. S. Herschel.
....	....	....	....	W. H. Wood.
tail at last; no k left.	....	....	Clear night; no moon...	A. S. Herschel.
phosphorescent tail second. Very short course.	....	Horizontal	....	Id.
traight fast meteor. te tail, 1 second.	....	....	....	Id.
tail for 0·4 second ..	8°............	Directed from β Pegasi..	....	Id.
starlike; no tail left	....	....	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. July 11	h m 11 56 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·7 second ...	Centre at ½ (... Pegasi.
12	11 15 p.m.	Ibid	= to Altair	White	1·1 second ...	From ½ (μ, ... Cygni to ½ (... Cygni.
12	11 18 p.m.	Ibid	=2½ mag.*	White	0·7 second ...	In continua... of the δ, ε Cephei, from the ... star.
12	11 28 p.m.	Ibid	=2nd mag.*	White	0·9 second ...	Appeared at ... Vulpeculæ.
12	11 50 p.m.	Ibid	= α Lyræ	Yellowish, then orange.	1·5 second ...	From 2° belo... Aquarii to ... below η Aqu...
12	11 55 p.m.	Ibid	=2½ mag.*	White	1·8 second ...	Commenced ... ι Pegasi. ... light was ... terrupted ... η Pegasi, ... the remai... of the fl... deflected u... wards.
12	11 56 p.m.	Ibid	=3rd mag.*	White	0·7 second ...	To within 7 ... degrees of δ ... dromedæ.
13	10 47 p.m.	Ibid	=2nd mag.*	White	1·1 second ...	From α Lyræ ... ½ (ξ, ο) ... culis.
13	10 48 p.m.	Ibid	=1½ mag.*	White	1·5 second ...	From Polaris t... S., and prece... κ Draconis.
13	11 17 p.m.	Ibid	=2nd mag., then =4th mag.*.	White, then yellow.	2·2 seconds ...	From ½ (λ, S) B... to ½ (γ ... Majoris, d ... Venat.).
13	11 28 p.m.	Ibid	=3rd mag.*	White	0·8 second ...	α Draconis to ... Ursæ Majori...
19	8 0 p.m. Before sunset.	Weston - super - Mare.	Brighter than Venus at maximum.	Bright yellow	2 or 3 seconds	Appeared N., a... 25° altitu... (measured). ... appeared be... clouds at alti... about 18° (... sured), N.W...
19	....	....	....	... .	....	Appeared in ... heavens, and ... appeared i... straight li... between t... evening sta... the setting s...

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
iite straight tail for 1·5 second.	12°	Directed from λ Andromedæ.	....	A. S. Herschel.
ll straight, white, 3·5 econds.	....	....	....	Id.
ry short course, not uite straight. No tail r sparks.	2°...........	....	....	Id.
ghtest at first appearnce.	....	Directed from η Cygni..	....	Id.
all at last, and red; o tail or sparks; no rain left.	....	Horizontal .... 	Low in S.E.	Id.
light at reappearance as less bright than at rst.	15°	The last 5° were deflected upwards a few degrees.	....	Id.
light was brighter t first than at last.	7° or 8° ...	Directed from ε Cygni..	....	Id.
tail or sparks...........	....	....	....	Id.
shy appearance	....	....	....	Id.
llar at first and white, fterwards misty and ellowish.	....	....	Low in N.W.	Id.
e stellar nucleus. rightest at first.	....	....	....	Id.
tail was observed, nor arks, probably on account of sunlight.	....	Apparently the same path as that of July 19, 1862, 11^{h} 17^{m} p.m.	See preceding Report (Catalogue).	W. H. Wood.
n about mid-heavens l took its course in a esterly direction.	....	The streak remained as a flash of fire for 30 seconds, and as a straight bluish cloud for 5 minutes. In 23 minutes it changed its figure from a direct line and disappeared, fading equally all over.	Seen in the early part of the evening, when in reality it was quite day; only Venus and the new moon could be discerned in the sky.	Correspondent to 'Hereford Journal.'

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. July 19	h m About 8 p.m.	Leominster (Herefordshire).	Singular meteor or shooting-star; = to 1st mag.*.	....	Traversed a longer distance than usual.	In the N.W.......
19	About 8 30 p.m.	....	As large as a Pigeon's egg.	Clear white ...	Moved slowly	An unusual appe ance in the nor western sky. (Place in the sky.)  W. N. Horizon line.
19	About 8 30 p.m.	Kingswinford (Birmingham).	Like a firework ...	Bright mauve colour, edged with pink.	....	Burst betwee Venus and moon.
19	Very shortly after sunset.	Hay (near Hereford, S. Wales).	....	....	....	The luminous str extended fi about alt. (measured), alt. 36° or (measured), actly over point of suns
22	9 21 p.m.	Weston-super-Mare.	At first = to Capella, then = to Jupiter.	Brilliant white	$1\frac{1}{3}$ second ...	From β Cassiop to β Cephei.
26	5 51 p.m.	Cranford Observatory; W. Long. $0^h\ 1^m\ 37^s{\cdot}53$.	Looked larger in disc and brighter than Arcturus.	Different in colour from Arcturus.	About $\frac{1}{2}°$ in 2 seconds.	Centre. R.A. 14 30ˢ, N. Decl. 53′ 46″.  Arcturus tr sited 4ᵐ 14ˢ af wards (along horizontal wi

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	Appeared to burst and send out bright rays in all directions. A path of vapour curved at each end remained more than a quarter of an hour.	Seen by daylight. The path of vapour contrasted strongly with the colour of the sky.	J.K., correspondent to the 'Irish Times.'
nall star or piece of fire falling down, from whose sides issued jets of thick, light, cloudy smoke in a clear white streak 15° long and ¼° wide. The meteor burst, and the streak took a zigzag form, leaning towards the W., appearing to lie lat; it then faded away. The nucleus descended o the horizon before it ourst.	....	From left to right	The meteor burned for a minute or two, but the streak for a much longer time.	W. Sandwick, communicated by T. W. Webb.
m S. to W.	....	After the nucleus disappeared, there remained a tail for 3 or 4 minutes, which broke into segments like 'mare's-tails,' and vanished by degrees.	....	Communicated by T. W. Webb.
e luminous streak assumed a zigzag form efore disappearance. 	....	Slanting downwards slightly from left to right; almost vertical.	Seen by four persons at Hay. The same meteor was described in the Birmingham newspapers.	Id.
zed out or became elongated just before extinction. No tail or sparks.	....	....	....	W. H. Wood.
o S.; vertical. The tazimuth instrument as *clamped* in the median, and in altitude, ring the passage of e meteor and of Arcrus.	....	The spurious disc appeared larger and brighter than that of Arcturus, and of a different colour. No change of appearance.	A meteor was noticed by daylight on a previous occasion while searching for Venus with the naked eye.	W. De la Rue.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. July 26	h m 11 0 p.m.	Weston - super - Mare.	Bright meteor......	Red	....	....
27	10 20 p.m.	Greenwich	= 1st mag.*	....	5 seconds......	From the zenit disappearing about 10° or 15 above the horizo due W.
27	10 35 p.m.	Ibid...............	= 1st mag.*	Straw colour..	2 seconds......	Appeared in S.W at altitude 50 disappearing i the S. at altitu 20°.
27	10 40 p.m.	Ibid...............	Small	....	2 seconds......	Passed slowly fro the zenith t wards the N.
28	9 57 p.m.	Ibid...............	= 1st mag.*	Blue	10 seconds ...	Passed from t neighbourhood of Jupiter to t western horizo
31	9 30 p.m.	Weston - super - Mare.	Large; Venus-like	Same colour as the moon.	....	From the S.W. (Serpens) towar the W.
31	11 0 p.m.	Hawkhurst (Kent).	= 3rd mag.*	....	0·6 second ...	ε Ursæ Minoris o Camelopardal
31	11 12 p.m.	Ibid	= 1st mag.* (+)...	....	0·8 sec., rapid	γ Cephei to γ Ur Minoris.
31	11 33 p.m.	Ibid	= 3½ mag.*	Orange.........	0·8 second ...	From r Custo to 2° bel Polaris.
Aug. 1	11 5 p.m.	Ibid	= 2nd mag.*	Yellow	0·8 second ...	ψ Cassiopeiæ to Cephei.
2	11 40 p.m.	Ibid	= 2nd mag.*	White	0·7 second ...	o Custodis to Camelopardali
3	11 47 p.m.	Ibid	= 3rd mag.*, then = 5th mag.*.	White	1·5 second ...	δ Ursæ Minoris t Ursæ Majoris.
5	11 20 p.m. or 11 30 p.m.	Ibid	> ♃	White	1·1 second ...	From f Pegasi t Capricorni.
8	10 9 p.m.	Ibid	= 2nd mag.*	White	1 second	(e) to (σ) Sa tarii.
8	10 10 p.m.	Ibid	= 2nd mag.*	Yellow	1·4 second ...	(m) Custodis (Q) Camelo dali.
8	10 15 p.m.	Southsea (Portsmouth).	= 2nd mag.*	Yellow	1 second	To ⅓ (ε, β) dromedæ, h way from (ν) dromedæ.
8	10 20 p.m.	Ibid	= 3rd mag.*	White	1 second	....
8	10 24 p.m.	Hawkhurst (Kent).	= 2nd mag.*	White	1 second	Fell vertically below (ν) O uchi.
8	10 28 p.m.	Southsea (Portsmouth).	= 2nd mag.*	White	1 second	From ½ (ζ Peg η Aquarii), way to γ gasi.

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
obular; no tail or sparks	....	Downwards from left to right.	....	Communicated by W. H. Wood.
ght blue train several degrees in length.	....	....	....	J. MacDonald.
ne	....	Inclined	....	Id.
....	....	....	....	Id.
ight train	....	Nearly perpendicular ...	Three other small meteors seen between 10^h and 10^h 20^m.	Id.
an acute angle with the perpendicular.	....	....	Descended	Communicated by W. H. Wood.
ishy appearance	....	....	....	A. S. Herschel.
llar; brightest at first..	....	....	A fine object	Id.
ghtest at middle; parkled.	....	....	....	Id.
shy appearance	....	....	Sky hazy; moon high S.E.	Id.
ht train, remained 1 econd.	....	....	Sky hazy; moon S.E....	Id.
er disappearing for 2° r3°, it reappeared for 6° r 8° as a misty object, ery faint.	20° or 25°..	Vertically down	Moon in S.E.; sky hazy	Id.
train or sparks	....	....	Brightest at middle of its path, which was long and rapid. A very fine object.	Id.
n half a second.........	....	....	....	Id.
ow tail, and sparks accompanied the flight.	....	....	No track left	Id.
....	....	....	....	W. Penn.
....	....	....	....	Id.
rain or sparks	....	Vertically down	....	A. S. Herschel.
....	....	....	....	W. Penn.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 8	h m s 10 28 p.m.	Weston - super - Mare.	>1st mag.*	Brilliant blue	0·75 second ...	From R. A. 70° N. Decl. 54° t R. A. 74°, N Decl. 44°.
8	10 29 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	From R. A. 36° N. Decl. 54° t R. A. 46°, N Decl. 53°.
8	10 29 30 p.m.	Hawkhurst (Kent).	=2½ mag.*	White	1 second	From (α,β) Equule to α Aquilæ.
8	10 38 p.m.	Southsea (Portsmouth).	=2nd mag.*	White	1½ second ...	From 2° below γ Aquarii t 2° below Aquarii.
8	10 39 p.m.	Weston - super - Mare.	=2nd mag.*	Blue, white....	1 second	From R. A. 357° N. Decl. 59° t R. A. 37°, N Decl. 69°.
8	10 40 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	1·2 second ...	To α Capricorn one quarter o the way from Delphini and a far again.
8	10 47 p.m.	Ibid	=1½ mag.*	White	1 second	From ½ (η Andromedæ, ψ Piscium) to Piscium.
8	10 47 p.m.	Weston - super - Mare.	=to Sirius	White, then blue.	1·5 second ...	From R. A. 27°, N Decl. 7° to R. A 20°, S. Decl. 2°
8	10 48 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From R. A. 30 N. Decl. 29° t R. A. 21°, N Decl. 19°.
8	10 49 p.m.	Ibid	=to Venus at maximum brightness.	Brilliant yellow.	1·5 second ...	From R. A. 30°, N Decl. 29° to R. A 25°, N. Decl. 17
8	10 49 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·3 second ...	Centre at β Pega
8	10 50 p.m.	Weston - super - Mare.	=1st mag.* (?) ...	Ruddy	....	From R. A. 322 N. Decl. 30° R. A. 312°, Decl. 3°.
8	10 51 p.m.	Hawkhurst (Kent).	=1st mag.*.........	Yellow	1 second	Centre at μ Serpentis.
8	10 52 p.m.	Weston - super - Mare.	=3rd mag.*	Blue	1 second	From R. A. 322 N. Decl. 30° R. A. 312°, Decl. 3°.
8	10 53 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·6 second ...	Centre at ε Bootis.
8	10 58 p.m.	Weston - super - Mare.	>than 1st mag.*..	Ruddy	1 second	From R. A. 27 N. Decl. 7° R. A. 20°, Decl. 0°.

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	18°	....	....	W. H. Wood.
....	....	....	....	Id.
train or sparks	....	....	....	A. S. Herschel.
....	....	....	....	W. Penn.
't a long slender thread of light.	....	....	....	W. H. Wood.
train or sparks	....	....	....	A. S. Herschel.
train or sparks	....	....	....	Id.
....	....	....	....	W. H. Wood.
....	....	....	....	Id.
ery bright meteor; red n off side and rear and pon its contour. Short lhering tail; left no ack.	....	....	Appeared stationary an instant before disappearance.	Id.
ghtest at centre	6°...........	Horizontal .... ⟶	....	A. S. Herschel.
r the red luminous ain was seen, which sted 3 seconds.	....	....	....	W. H. Wood.
rain or sparks	6°...........	Directed from κ Herculis.	....	A. S. Herschel.
meteor showed intermittent light.	....	....	....	W. H. Wood.
rain or sparks	6°...........	Directed from α Coronæ	....	A. S. Herschel.
uddy tail, remained seconds.	....	....	....	W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 8	h m s 10 58 p.m.	Hawkhurst (Kent).	= to Jupiter	White	2·8 seconds ...	From β Pegasi γ Aquilæ. meteor cros these stars c to its beginn and end.
8	10 58 p.m.	Southsea (Portsmouth).	= to Venus at her brightest.	Yellow	3 seconds......	From as below δ An medæ as δ be π, nearly t Pegasi.
8	11 1 p.m.	Hawkhurst (Kent).	= 2nd mag.*	Yellow	1 second	To 17 Draco halfway fron Draconis.
8	11 3 30 p.m.	Ibid	= 3rd mag.*	Yellow	0·8 second ...	From $\frac{1}{2}$ (o Dra nis, κ Cygni), $\frac{1}{3}$ (γ Draconi Lyræ).
8	11 4 30 p.m.	Ibid	= 3rd mag.*	Yellow	0·5 second ...	From $\frac{1}{2}$ (δ, β) I culis.
8	11 5 p.m.	Ibid	= 3rd mag.*	Yellow	0·7 second ...	From γ to Aquilæ.
8	11 11 p.m.	Weston - super - Mare.	= 2nd mag.*	Blue	....	From R. A. N. Decl. 10° R. A. 350°, Decl. 0°.
8	11 24 p.m.	Hawkhurst (Kent).	= $2\frac{1}{2}$ mag.*	Yellow	0·5 second ...	From q Pegasi (r, s) Piscium
8	11 25 p.m.	Weston - super - Mare.	= to Antares	Similar to Antares.	0·75 second...	From R. A. 3 S. Decl. 15° R. A. 293°, Decl. 20°.
8	11 42 p.m.	Hawkhurst (Kent).	= 3rd mag.*	White	1 second	From i to λ otis.
8	11 45 p.m.	Euston Road (London).	= 2nd mag.*	Bluish white...	0·8 second ...	From κ Cephe near ι Hercu
8	11 46 30 p.m.	Hawkhurst (Kent).	= $3\frac{1}{2}$ mag.*	White	1 second	To $\frac{1}{4}$ (δ Serpe ζ Bootis), way from α ronæ.
8	11 48 30 p.m.	Ibid	= 3rd mag.*	White	1·1 second ...	To r Canum nat., from way η Ursæ joris.
9	8 9 30 p.m.	Ibid	> 1st mag.*	Yellow	1·5 second ...	To β Libræ $\frac{3}{4}$ way Arctu
9	8 32 p.m.	Ibid	= 2nd mag.*	White	1 second	To λ Ophi from halfw Herculis.
9	8 39 p.m.	Euston Road (London).	= 1st mag.*	White	....	From ϕ Perse θ Andromed

ppearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
red part upon the rear of the nucleus. Train 4′ wide, 40° long, white; disappeared equably throughout, in 4 secs.; spindle-shaped.	50°	Horizontal in S.E., left to right, at altitude about 30°.	No sparks, but a red colour in rear of the nucleus, which was white.	A. S. Herschel.
ery long train; feathery and broad in the centre.	....	....	....	W. Penn.
) train or sparks	....	....	....	A. S. Herschel.
) train or sparks	....	....	....	Id.
) train or sparks	3°............	Towards ι Ophiuchi ...	....	Id.
) train or sparks	....	....	....	Id.
) train or sparks	....	....	....	W. H. Wood.
train or sparks	....	....	....	A. S. Herschel.
train or sparks	....	....	....	W. H. Wood.
train or sparks	....	....	....	A. S. Herschel.
st seen at latter part of course; train 5°.	....	....	....	T. Crumplen.
ort train; meteor brightest at last; disappeared suddenly.	....	....	....	A. S. Herschel.
train or sparks	....	....	....	Id.
sparks or train; visible in the daylight.	....	.... 	Venus and Arcturus were visible, but no other stars.	Id.
train or sparks	....	....	....	Id.
5°.........................	....	....	....	T. Crumplen.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 9	h m s 8 47 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1 second	o Bootis to ½ (z Virginis.
9	8 59 p.m.	Euston Road (London).	=1st mag.*	Orange red ...	....	From between σ) to belov Ophiuchi.
9	9 12 p.m.	Greenwich Park..	....	....	2 secs., slow motion.	From a little be ½ (δ, ε) U Majoris to ı κ Draconis.
9	9 25 p.m.	Euston Road (London).	=3rd mag.*	....	....	From ρ to β I conis.
9	9 27 p.m.	Ibid	=2nd mag.*	Ruddy	0·3 second ...	Near α Aquilæ..
9	9 28 p.m.	Ibid	=3rd mag.*	Ruddy	0·2 second ...	From β Cygn α Sagittæ.
9	9 28 p.m.	Greenwich Park	Bright meteor......	Bright white..	Quick motion.	From η Ursæ joris to so what below A turus.
9	9 28 p.m.	Euston Road (London).	=3rd mag.*	Ruddy	0·2 second ...	From β Cygni Sagittæ.
9	9 32 p.m.	Ibid	=1·2 mag.*	Orange colour	2 seconds......	Position not not
9	9 34 p.m.	Ibid	=1·2 mag.*	Bluish	2 seconds......	From θ Cygni κ Lyræ.
9	9 38 p.m.	Greenwich Park	....	....	Quick, short path.	Passed across Ursæ Majoris
9	9 40 p.m.	Euston Road (London).	=2nd mag.*	Orange red ...	1·5 second ...	From ε Aquari α Capricorni.
9	9 40 30 p.m.	Greenwich Park	Very bright meteor	Bright white..	....	Passed directly cross α Drac towards the T
9	9 42 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1 second	From η Dracon ½ (δ, θ Coro
9	9 50 p.m.	Euston Road (London).	=3rd mag.*	....	....	From θ Cygni Lyræ.
9	9 52 15 p.m.	Hawkhurst (Kent).	= 1st mag.*, or brighter.	White, yellow, orange.	1·2 second ...	From ι Cygni (C, F) Hercu
9	9 53 p.m.	Cranford	Large and brilliant as Venus at her brightest.	....	Slow motion; about 2 secs.	From altitude al 60° downwa Centre S.W.
9	9 53 p.m.	Euston Road (London).	=1st mag.*	Red	0·5 second ...	From p Vulpe almost to Aquilæ.
9	9 57 15 p.m.	Hawkhurst (Kent).	= 3rd mag.*, then =Venus, then =3rd mag.*.	Yellowish white at maximum, ruddy at last.	2·3 seconds ...	Centre between Serpentis; c halfway fron Herculis, and ceeded an c distance onwa
9	9 58 p.m.	Euston Road (London).	=to α Lyræ	Ruddy	3 seconds ...	From a point tween (o, ν) pentis.
9	10 5 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	Centre exactly Aquilæ.

earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
parks; train ½ second	....	....	....	A. S. Herschel.
1 5° long...............	....	....	....	T. Crumplen.
1 of sparks	....	Towards the Pole	....	W. Airy.
....	....	....	....	T. Crumplen.
of 2½° in length ...	....	....	....	Id.
ain or sparks	....	....	....	Id.
1 red tail	....	....	....	W. Airy.
....	....	....	....	T. Crumplen.
visible through an ra-glass 20 seconds.	....	....	....	Id.
seen 8 seconds ugh an opera-glass.	....	....	....	Id.
....	....	Passed downwards	....	W. Airy.
3½°	....	....	....	T. Crumplen.
train of sparks......	....	Towards the Pole	....	W. Airy.
ted ½ second	....	....	....	A. S. Herschel.
2° in length	....	....	....	T. Crumplen.
sparks about the eus. Tail 15°, two ds, white.	....	....	Corresponds to Cranford and to Euston Road, 9^h 53^m p.m.	A. S. Herschel.
rain about 20° long	....	Shot almost vertically downwards.	....	W. De la Rue.
° long	....	....	....	T. Crumplen.
ain or sparks. een (α, ε) Ser- s the meteor ex- d suddenly to equal s, and immediately collapsed.	....	Almost vertically down, S.W.; alt. about 20°.	....	A. S. Herschel, J. F. W. Herschel, and others.
sparkled. A s envelope ntly surrounded Tail irregularly .	6°............	Directed from μ Ophiuchi.	....	T. Crumplen.
nained across θ e.	15°	Parallel to Milky Way...	....	J.F.W.Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 9	h m s 10 7 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·8 second ...	To υ Bootis, [illegible] $\frac{1}{3}$ way η [illegible] Majoris.
9	10 7 45 p.m.	Ibid	=2nd mag.*	White	0·7 second ...	From $\frac{1}{3}$ to $\frac{2}{3}$ [illegible] γ Serpentis [illegible] Scorpii.
9	10 12 p.m.	Euston Road (London).	=α Lyræ...........	Pale yellow ...	3 seconds......	From Scutum [illegible] eski to μ Sagit[illegible]
9	10 19 p.m.	Ibid	= to Venus.........	Orange colour	1·5 second ...	From ϵ Aquila[illegible] wards η Serp[illegible]
9	10 19 45 p.m.	Hawkhurst (Kent).	=1st mag.*.........	Orange.........	1·4 second ...	From $\frac{1}{2}(\xi,\beta)$ D[illegible] nis to β Her[illegible]
9	10 33 15 p.m.	Ibid	=2nd mag.*	White	0·8 second ...	From 2° over [illegible] turus.
9	10 34 p.m.	Euston Road (London).	=2nd mag.*	Bluish	1 second	Near β Andro[illegible]
9	10 40 p.m.	Hawkhurst (Kent).	=1·5 mag.*	Orange.........	1·4 second ...	From 3° left [illegible] to *d* Pegasi.
9	10 41 p.m.	Ibid	=2nd mag.*	Yellow	1 second	From 1° over [illegible] $\frac{1}{3}(\epsilon,\theta)$ Peg[illegible]
9	10 44 p.m.	Euston Road (London).	=α Lyræ...........	Ruddy	1·3 second ...	Near α Capric[illegible]
9	10 52 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	1 second	From ϕ Ursa[illegible] joris, onwa[illegible]
9	10 54 p.m.	Euston Road (London).	=α Lyræ...........	Ruddy	5 seconds......	Near η Aquar[illegible]
9	10 57 45 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·7 second ...	Disappeared [illegible] of δ Cassiope[illegible]
9	11 1 p.m.	Euston Road (London).	=3rd mag.*.........	Bluish	....	From μ to [illegible] dromedæ.
9	11 6 p.m.	Ibid	=1st mag.*.........	Ruddy	1 second	Between π, [illegible] dromedæ.
9	11 13 p.m.	Hawkhurst (Kent).	=3·5 mag.*	Yellow	0·8 second ...	From ζ Drac[illegible] way to χ He[illegible]
10	0 5 a.m.	Euston Road (London).	Illuminated the house-roofs.	....	$2\frac{1}{2}$ to 3 secs...	Conjectured 38° alt. on meridian.
10	0 5 a.m.	Hastings, Winchelsea, &c. (17 CoastGuardSta[s] near Hastings).	Unusually large. Diffused a bright light.	Bright white, tinged with blue.	5 or 6 seconds	Above Polaris[illegible] altitude abo[illegible] N.E. to W[illegible] tude 50°.
10	8 45 p.m. (9 30 p.m. Bologna M.T.).	Riv. Samoggia (midway between Bologna and Modena, North Italy).	One-sixth diameter of the moon. Cast shadows of trees, &c. more strongly than the moon.	Azure blue, or violet.	....	From a sho[illegible] tance E. [illegible] laris throug[illegible] Major to B[illegible] disappearin[illegible] Arcturus.
10	9 3 p.m.	Euston Road (London).	=1st mag.*.........	Bluish	0·5 second ...	From η Urs[illegible] joris to Ar[illegible]

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
l endured ½ second ...	....	....	....	A. S. Herschel.
in lasted ½ second......	....	....	....	Id.
train remained 8° in ngth.	....	....	....	T. Crumplen.
in remained upon the hole length of the path ½ seconds.	....	....	Train appeared to break up first near the termination, then faded gradually from each end to centre.	Id.
ow sparks about the ucleus. Tail 2 secs.	....	....	Corresponds to Euston Road, 10^h 19^m p.m.	A. S. Herschel.
n 6°	10°	Directed from η Ursæ Majoris.	....	Id.
rain remained 1° in ngth.	6° or 7° ...	From β to γ Andromedæ	....	T. Crumplen.
leus sparkled; long raight tail, lasted 2 conds.	....	....	....	A. S. Herschel.
ain remained	....	....	....	Id.
ain remained 7½° in ngth.	8° or 9° ...	θ Pegasi to α Capricorni	....	T. Crumplen.
rain or sparks	7°............	Directed from o Ursæ Majoris.	....	A. S. Herschel.
ous envelope round l nucleus. Train seen minutes in opera-glass.	8° or 9° ...	From ζ to γ Aquarii ...	Tail faded gradually at each extremity.	T. Crumplen.
ain remained for 1½ cond.	3°............	Directed from α Persei..	....	A. S. Herschel.
rain or sparks	....	....	....	T. Crumplen.
ain remained 5° in gth.	10°	From ι, κ, λ Andromedæ	....	Id.
in remained ½ second	....	....	....	A. S. Herschel.
....	....	....	A report followed	T. Crumplen.
of fire with red train moderate length.	50° or 60°..	From E.N.E. to W.S.W., slightly rising.	Exploded at a point about ⅔ds of its path. Disappeared suddenly. A report followed.	W. E. Buck, T. Webb, &c.; communicated by F. W. Gough.
st a white shooting-t. Expanded suddenly r first third part of its ht. At the middle of path a gaseous en-pe and scintillations nded some distance n the head. The eor contracted ra-y near Arcturus, and ently disappeared.	....	....	The train near the centre endured three minutes, becoming serpentine, fusiform (very wide at the middle), fading rapidly at the ends. No report heard. Seen also at Bologna by Dr. Casoni.	J. Joseph Bianconi.
n remained 6½° long	....	....	....	T. Crumplen.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 9 3 p.m.	Cranford (Middlesex).	=2nd mag.*	....	Nearly 1 sec...	At elevation (about 8°, a li to the E. of S
10	9 5 p.m.	Ibid	Very bright	....	....	Across Caprico:
10	9 5 20 p.m.	Ibid	....	....	....	Across Pegasus
10	9 6 p.m.	Weston - super - Mare.	=Sirius	Vivid blue ...	1 second	Appeared at γ gittarii.
10	9 9 p.m.	Ibid	=Sirius	Blue-white ...	1 second	From γ Equul μ Aquilæ.
10	9 13 p.m.	Ibid	=Venus	Yellow	2·5 seconds ...	From N. by ½ W., alt. : downwards the horizon.
10	9 15 p.m.	Euston Road (London).	=2nd mag.*	White	0·5 second ...	From λ to ε O uchi.
10	9 21 30 p.m.	Hawkhurst (Kent).	=1st mag.*, then =Jupiter.	White	3 seconds......	From θ Coron ⅓ (μ Serpen Libræ).
10	9 21 35 p.m.	Cranford (Middlesex).	A very brilliant meteor.	....	....	From α Lyræ tween α Oph and α Herc
10	9 22 30 p.m.	Hawkhurst (Kent).	=1st mag.*.........	....	1 second	From θ Booti ½ (α Coror Bootis).
10	9 23 30 p.m.	Euston Road (London).	Splendid meteor, = to Venus.	Bluish white..	1 second	From ⅓ (α, δ) culis to ζ (uchi.
10	9 24 30 p.m.	Ibid	=1st mag.*.........	Bluish white..	1 second	From ½ (α, κ) culis to 3° l ε Ophiuchi.
10	9 25 30 p.m.	Ibid	=1st mag.*.........	Bluish white..	1 second	From ο Tauri niat. to ½ (Ophiuchi.
10	9 26 p.m.	Ibid	=1st mag.*.........	Bluish white..	1 second	ε Pegasi to θ A
10	9 26 p.m.	Greenwich Observatory.	=1st mag.*.........	Blue............	1 second	From left Corona to W. horizon.
10	9 26 p.m.	Weston - super - Mare.	=1st mag.*.........	Red	1 second	From the mou Ursa Major Ursæ Major
10	9 28 p.m.	Ibid	=Venus	Blood - red colour.	....	Appeared at above α A to 1° abov horizon.

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	W. De la Rue.
....	10°		....	Id.
....	....	 In direction of a line drawn from δ to ϵ Cygni.	....	Id.
....	8°...........	40° to right of perpendicular.	....	W. H. Wood.
vhite train remained ...	....	....	....	Id.
.train or sparks	....	Perpendicularly down...	The meteor disappeared behind the horizon.	Id.
:rain remained 5° in :ngth.	....	....	....	T. Crumplen.
head scintillated ith red or yellow)arks. Tail endured seconds, near α Ser-entis; white.	40°	....	The rest of the tail vanished quickly. Corresponds to Cranford, 9^h 21^m 35^s p.m., and to Euston Road, 9^h 23^m 30^s p.m.	A. S. Herschel.
a long train, visible om 1 to 2 seconds of me.	40° or 45° in length.	....	....	W. De la Rue.
a white train	....	....	....	A. S. Herschel.
·rain 10½° long re-ained visible in an)era-glass 4½ minutes :ar the end; spindle-aped, and fading from e ends to the centre.	Nearly 40°..	....	For a representation of the train see Appendix.	T. Crumplen.
ain remained 10½° in ·igth.	....	....	....	Id.
ain remained 10½° in)gth.	....	....	....	Id.
ain remained 8½° in)gth.	....	....	....	Id.
:a white train	20° + ...	....	Lost behind trees after travelling about 20°.	W. C. Nash.
....	....	....	....	W. H. Wood.
rain or sparks	....	Perpendicularly down...	The colour perhaps atmospheric.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 9 28 30 p.m.	Cranford (Middlesex).	=1st mag.*	....	....	Disappeared ab ½° from α Lyr
10	9 29 p.m.	Weston-super-Mare.	=1st mag.*	White	2·5 seconds ...	Appeared at γ gasi.
10	9 29 p.m.	Greenwich Observatory.	=2nd mag.*	Blue	1 second	From γ Drac across α Cor towards the horizon.
10	9 31 p.m.	Euston Road (London).	=2nd mag.*	Ruddy	0·5 second ...	From θ Aquil through κ tinoï.
10	9 31 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	1½ second ...	From δ Ursæ M joris to h, m Ca Venatici.
10	9 35 p.m.	Euston Road (London).	=α Lyræ	Blue	0·4 second ...	From between quuleus & Del nus to θ Aquil
10	9 36 p.m.	Hawkhurst (Kent).	=Jupiter	White	1·7 second ...	From κ Herculi ⅓ (μ Serpenti Ophiuchi).
10	9 36 30 p.m.	Greenwich Observatory.	=1st mag.*	Blue	1 second	Fell in the W. a line from Herculis.
10	9 37 p.m.	Euston Road (London).	=Venus	Bluish	....	From κ Ophiuc a point near ζ O uchi, in R.A. 24 S. Decl. 8½°.
10	9 38 50 p.m.	Cranford (Middlesex).	=2nd mag.*	....	....	From χ Cygni Aquilæ.
10	9 40 5 p.m.	Ibid	Brilliant meteor ...	....	....	Centre of path at α Pegasi, or two deg above.
10	9 40 30 p.m.	Hawkhurst (Kent).	=2½ mag.*	White	1 second	From 5° belo Cygni to phinus.
10	9 44 p.m.	Euston Road (London).	=3rd mag.*	White	....	To ι Aquilæ....
10	9 44 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	....	Appeared at γ gasi.
10	9 44 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	1·2 second ...	To h Canum V ticorum, fro ε Ursæ Maj and 4° furth
10	9 44 45 p.m.	Ibid	=2nd mag.*	Yellow	1·2 second ...	ι Cephei to η Ce
10	9 45 p.m.	Euston Road (London).	....	....	....	From ½ (α, π Bootis.
10	9 46 10 p.m.	Cambridge Observatory.	....	....	....	First appeared altitude 27 azimuth 257° from S.
10	9 46 15 p.m.	Hawkhurst (Kent).	>Venus at maximum brightness.	Brilliant yellow.	....	Centre at c Tr gulæ.
10	9 47 p.m.	Euston Road (London).	=1st mag.*	White	....	A few deg below β, ε dromedæ.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...train or sparks	....	Directed from Cassiopeia to α Lyræ.	....	W. De la Rue.
...white train 25° in ...ngth remained after ...isappearance of the ...eteor.	....	Inclined 40° to left of perpendicular.	....	W. H. Wood.
...train or sparks	40°	....	....	W. C. Nash.
...rain remained 5° in ...ngth.	....	From ε Pegasi	....	T. Crumplen.
...n endured 2 seconds...	....	....	....	A. S. Herschel.
....	....	....	....	T. Crumplen.
...train endured 3 secs...	....	....	Corresponds to Greenwich, 9h 36m 30s, and to EustonRoad, 9h 37m p.m.	A. S. Herschel.
...ks at disappearance of t... meteor, and a white t...in remained.	15°	....	....	W. C. Nash.
...a seen for some time i... an opera-glass, fading t...wards the centre from t... ends.	....	....	....	T. Crumplen.
....	....	....	....	W. De la Rue.
...a long train...........	....	....	....	Id.
...a endured 3 seconds...	....	....	Position doubtful	A. S. Herschel.
....	10°	Directed from η Pegasi	....	T. Crumplen.
....	10°	45° to right of perpendicular.	....	W. H. Wood.
...l remained visible ...conds.	....	....	....	A. S. Herschel.
t...in remained visible ...conds.	....	Directed from α Persei..	....	Id.
...a of 5° remained ...	7°...........	Directed from ρ Bootis	....	T. Crumplen.
...t train	....	Moved towards 4 hour of a watch-face held with 12h vertical.	....	J. C. Adams.
...tin or sparks	15°	Towards α Arietis	Corresponds to Cambridge, 9h 46m 10s p.m.	A. S. Herschel.
...5° long	12°	β to ε Andromedæ ...	....	T. Crumplen.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 9 47 p.m.	Greenwich Observatory.	Brighter than Venus	Bluish white...	½ second	In the E.; mo almost horiz ally southwa above α Arie
10	9 47 29 p.m.	Cambridge Observatory.	....	....	....	....
10	9 47 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·8 second ...	From γ Androm to β Triangu
10	9 47 30 p.m.	Ibid	=2nd mag.*	Yellow	0·8 second ...	From c Camelo dali to 2° un neath L Cam pardali.
10	9 48 p.m.	Euston Road (London).	=1st mag.*	....	....	From γ Andro dæ towards Arietis.
10	9 48 p.m.	Weston-super-Mare.	>1st mag.*	White	0·5 second ...	....
10	9 49 18 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commencemen 235° W. fron altitude 70°.
10	9 50 33 p.m.	Ibid	=2nd mag.*	....	....	Commenced a point 241°·5 from S., alti 62°·5.
10	9 53 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	1 second	τ Herculis to ζ ronæ.
10	9 53 28 p.m.	Cambridge Observatory.	....	....	....	Commenced a point 12° from S., alti 54°·5.
10	9 53 30 p.m.	Greenwich Observatory.	=1st mag.*.........	Blue............	1 second	Moved rapidly α Lyræ acro Herculis, and further.
10	9 53 45 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	From c Comæ renices to under υ Boo
10	9 54 12 p.m.	Cambridge Observatory.	....	....	....	....
10	9 54 15 p.m.	Hawkhurst (Kent).	=Venus at brightest.	Yellow	1·8 second ...	From ⅓ to ⅔ M Camelopar
10	9 54 24 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced W. from S., tude 53°.
10	9 56 45 p.m.	Ibid	=3rd mag.*	....	....	Commenced 90 from S., alti 48°.
10	9 56 45 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	1 second	From 5 Can. naticorum t above d Can. naticorum an further.
10	9 57 p.m.	Euston Road (London).	=1st mag.*.........	....	....	θ Pegasi to k N Aquarii.
10	9 57 15 p.m.	Ibid	=3rd mag.*	White	0·4 second ...	From β Cygni Aquilæ.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	5° ±	Almost horizontal	....	W. C. Nash.
...hooting-star of ordinary ...ppearance.	....	To left; horizontal......	....	....
...in endured $\frac{1}{2}$ second ...	....	....	....	A. S. Herschel.
...in endured $\frac{1}{2}$ second ...	....	....	....	Id.
...t a train 4° long	10°	....	....	Id.
...white tail 10° long en-...ured for a few seconds.	....	50° to right of perpendicular.	....	W. H. Wood.
....	....	Towards $2\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
... a train	....	Towards $2\frac{1}{4}$ hour of a watch-face held with 12^h vertical.	....	Id.
...a endured 1 second ...	....	....	Corresponds to Cambridge, 9^h 53^m 28^s p.m.	A. S. Herschel.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...n lasted less than 1 ...cond.	40°	From zenith to W.	....	W. C. Nash.
....	....	....	....	A. S. Herschel.
...ooting-star of ordinary ...pearance.	....	....	....	....
...a thick, yellow streak ...f 30 seconds.	....	....	....	A. S. Herschel.
...a train 12° in length..	....	Towards $2\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
....	....	Towards 7 or 8 hour of a watch-face held with 12^h vertical.	....	G. Plummer.
...h streak for 2 seconds	....	....	Corresponds to Cambridge, 9^h 56^m 45^s p.m.	A. S. Herschel.
...il or sparks	....	....	....	T. Crumplen.
...il or sparks	....	....	....	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 9 57 40 p.m.	Cranford (Middlesex).	Brilliant meteor ...	....	....	From α Lyræ, of the way to Serpentis.
10	9 57 45 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	From η Ursæ M joris to ϵ Booti
10	9 58 p.m.	Greenwich Observatory.	=2nd mag.*	Blue	1 second	From ρ Coron towards the W horizon.
10	9 59 p.m.	Euston Road (London).	=2nd mag.*	Bluish	....	Across ϵ Herculis
10	9 59 15 p.m.	Ibid	=2nd mag.*	Bluish	....	Across ϵ Herculis
10	9 59 27 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced 143° W. from S., altitude 41°.
10	10 0 45 p.m.	Hawkhurst (Kent).	>1st mag.*	Orange colour	1 second	From b to 1° under 12 Lyncis.
10	10 0 45 p.m.	Ibid	>1st mag.*	Orange colour	1 second	From $\frac{1}{3}$ (b Lyncis b Camelopardal to $2\frac{1}{2}$° over Lyncis.
10	10 0 55 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 211° W. from S., altitude 42°·5.
10	10 0 57 p.m.	Ibid	....	....	....	....
10	10 1 p.m.	Euston Road (London).	2> α Lyræ........	....	....	From ι Lyræ, between (C, F) Herculis and a few degrees further.
10	10 1 12 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 22° W. from S., altitude 36°·5.
10	10 1 30 p.m.	Greenwich Observatory.	= α Lyræ........	Very bright blue.	$1\frac{1}{2}$ second ...	From α Lyræ across α Herculis, and or 8° further.
10	10 1 57 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 322 W. from S., altitude 42°.
10	10 2 p.m.	Hawkhurst (Kent).	=to Sirius	Orange colour	1·2 second ...	To ζ Cygni from g Lacertæ.
10	10 3 p.m.	Euston Road (London).	Meteor=to Venus	....	....	From θ Pegasi to α Equulei.
10	10 3 45 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	Centre at m Lyncis
10	10 4 6 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 211 W. from S., altitude 26°.
10	10 4 20 p.m.	Ibid	=2nd mag.*	....	....	Commenced 175° W. from S., altitude 28°·5.

earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
n about 4 seconds				W. De la Rue.
rain or sparks				A. S. Herschel.
t train	15° to 20°			W. C. Nash.
				
n as long as the visible gth.		ρ to δ Herculis	Two meteors, both alike, and following precisely the same course.	T. Crumplen.
n as long as the visible gth.		ρ to δ Herculis		Id.
		Towards $8\frac{1}{2}$ hour of a watch-face held with 12^h vertical.		J. C. Adams.
ail or sparks left				A. S. Herschel.
ain or sparks left				Id.
		Towards 9 hour of a watch-face held with 12^h vertical.		James Challis.
ing-star of ordinary earance.				
ain endured a short e, $7\frac{1}{2}°$ in length.				T. Crumplen.
		Towards 5 hour of a watch-face held with 12^h vertical.		G. Plummer.
in endured 1 or 2 onds.	35° to 40°			W. C. Nash.
t luminous train		Vertically downwards		G. Plummer.
luminous train en- ed 8 seconds.				A. S. Herschel.
				T. Crumplen.
	6°	Directed from Capella		A. S. Herschel.
		Towards 8 hour of a watch-face held with 12^h vertical.		J. C. Adams.
t luminous train		Towards $8\frac{1}{2}$ hour of a watch-face held with 12^h vertical.		Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 10 4 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	....	b Lyncis to 1° of θ Ursæ M[illegible] joris.
10	10 5 p.m.	Ibid	=to Sirius	Orange colour	1·3 second ...	From 6° belo[illegible] to 3½° belo[illegible] Ursæ Majoris
10	10 5 p.m.	Greenwich Observatory.	=2nd mag.*	Bluish white...	1 second	From o Ursæ M[illegible] joris beneath U[illegible] Major towar[illegible] horizon.
10	10 5 p.m.	Hawkhurst (Kent).	=1st mag.*	Orange colour	1·3 second ...	From 6° belo[illegible] to 3½° belo[illegible] Ursæ Majoris
10	10 5 45 p.m.	Ibid	=to Sirius	Orange colour	1·2 second ...	From ι to κ Ce[illegible]
10	10 5 45 p.m.	Ibid	=to Sirius	Orange colour	1·2 second ...	From ι to θ Ce[illegible]
10	10 6 6 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 3[illegible] W. from S., [illegible] tude 49°.
10	10 6 15 p.m.	Hawkhurst (Kent).	=to Sirius	Orange colour	....	From θ Hercul[illegible] κ Ophiuchi [illegible] 5° further.
10	10 6 35 p.m.	Cranford (Middlesex).	Brilliant meteor ...	....	....	From ½ (γ Sag[illegible] δ Delphini) ½ (κ, λ) [illegible] tinoï.
10	10 6 46 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 5° from S., altit[illegible] 31°·5.
10	10 7 30 p.m.	Hawkhurst (Kent).	=1st mag.*	White	....	From ½ (β, μ) [illegible] Andromedæ.
10	10 7 30 p.m.	Ibid	=to Sirius	Orange colour	....	From 3° befor[illegible] to 3° beyon[illegible] Andromedæ.
10	10 8 p.m.	Euston Road (London).	=1st mag.*	Ruddy	1·5 second ...	From g Lace[illegible] to γ Delphin[illegible]
10	10 8 p.m.	Greenwich Observatory.	Very brilliant; =1st mag.*.	Bluish	1 second	From δ Androm[illegible] across γ Peg[illegible]
10	10 8 p.m.	Hampton (Middlesex).	=1st mag.*; very brilliant.	....	....	From β Cassio[illegible] to γ Cygni.
10	10 8 3 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 3[illegible] W. from S., [illegible] tude 42°·5.
10	10 8 30 p.m.	Hawkhurst (Kent).	=1st mag.*	....	1·6 second ...	From ½ (κ L[illegible] β Draconis) ac[illegible] ρ Herculis t[illegible] Herculis, and further.
10	10 8 46 p.m.	Cambridge Observatory.	....	....	....	Commenced [illegible] W. from S., [illegible] tude 74°.

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	Corresponds to Cambridge, $10^h 4^m 20^s$ p.m.	A. S. Herschel.
....	....	Directed from *b* Camelopardali.	....	Id.
train or sparks	25°	 About 12° from horizontal.	....	W. C. Nash.
rain or sparks	....	Directed from *b* Camelopardali.	....	A. S. Herschel.
minous streak endured r 4 seconds upon the hole length of the sible flight.	....	....	....	Id.
minous streak endured seconds upon the hole course.	....	....	Corresponds to Euston Road, $10^h 8^m$ p.m.	Id.
a luminous train ...	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	James Challis.
1 4 seconds; much ightest at the middle the course.	30°	....	Corresponds to Cranford, $10^h 6^m 35^s$ p.m.	A. S. Herschel.
train endured for arcely half a second.	20°	....	....	W. De la Rue.
a luminous train	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	James Challis.
rain or sparks	....	....	....	A. S. Herschel.
rain or sparks	....	....	....	Id.
a train 12° in length..	....	....	....	T. Crumplen.
a slight train	20°	....	....	W. C. Nash.
a slight train	....	....	....	H. Temple Humphreys.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	G. Plummer.
a luminous streak ...	....	....	Corresponds to Euston Road, $10^h 9^m$ p.m.	A. S. Herschel.
....	....	Towards $4\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	....	James Challis.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 10 9 p.m.	Euston Road (London).	=1st mag.*	White	....	From ½ (β Cyg β Lyræ) to (S Tauri P niat., θ Serpentis).
10	10 10 15 p.m.	Cambridge Observatory.	....	....	....	Commenced 58 W. from S., a tude 63°·5.
10	10 11 p.m.	Hampton (Middlesex).	A 1st mag. meteor; very bright.	....	....	From 1° above Andromedæ 4° below ι gasi.
10	10 11 25 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 2 W. from S., a tude 58°.
10	10 11 30 p.m.	Greenwich Observatory.	>than 1st mag.*...	Brilliant blue..	2 seconds ...	From ½ (λ Andmedæ, δ Ceph to 5° left of Vulpeculæ.
10	10 11 30 p.m.	Hawkhurst (Kent).	A meteor brighter than Sirius.	Yellow	1·4 second ...	From 1½° right ψ Cephei to (η Cephei, Cygni).
10	10 12 p.m.	Euston Road (London).	> than Venus at its brightest.	....	0·5 second ...	From R. A. 28 S. Decl. 10° R. A. 277°, Decl. 20°.
10	10 12 p.m.	Hampton (Middlesex).	=1st mag.*	....	....	From ½ (A, g) Dconis across Herculis, and or 8° further.
10	10 12 30 p.m.	Cranford Observatory.	Very brilliant	....	....	Passed between γ Herculis.
10	10 13 p.m.	Weston-super-Mare.	=to Sirius	White	½ second	From δ Bootis t Bootis.
10	10 13 20 p.m.	Wisbech (Cambridgeshire).	Bright; =2nd magnitude *.	Blue	1½ second ...	From ι Cassiop to T Cephei.
10	10 13 40 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced W. from S., a tude 38°·5.
10	10 14 p.m.	Greenwich Observatory.	=3rd mag.*	Blue	Less than 1 sec.	From α Cassiop to ξ Androme
10	10 14 p.m.	Euston Road (London).	=1st mag.*	....	0·7 second ...	Passed between and γ Serpen from Gemma.
10	10 14 15 p.m.	Hawkhurst (Kent).	=α Lyræ...........	White	1 second	From θ to 3° sh of ε Bootis.
10	10 14 18 p.m.	Cambridge Observatory.	....	....	....	Commenced 3 W. from S., a tude 42°·5.
10	10 14 25 p.m.	Ibid	....	....	....	Commenced 4 W. from S., a tude 45°·5.
10	10 14 40 p.m.	Cranford Observatory.	Bright meteor	....	....	Disappeared cl to α Lyræ.

ppearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	T. Crumplen.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	G. Plummer.
ain remained 2 seconds..	....	....	....	H. Temple Humphreys.
ft a luminous train 18° long.	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	James Challis.
fine train, which re- ained visible 3 seconds.	....	....	....	W. C. Nash.
e train was orange, and asted 6 seconds, in two atches, being broken at Cephei.	....	....	Corresponds to Hampton, 10^h 11^m p.m.; Cambridge, 10^h 11^m 25^s p.m.; and Greenwich, 10^h 11^m 30^s p.m.	A. S. Herschel.
t a fine luminous train, vhich faded in $3\frac{1}{2}$ or 4 econds.	....	....	....	T. Crumplen.
ght train	....	....	....	H. Temple Humphreys.
t a bright train for 4 r 5 seconds.	....	....	....	W. De la Rue.
t a white train for $2\frac{1}{2}$ econds.	....	....	10^h 8^m p.m. lightning or meteor-flash; clouds increasing.	W. H. Wood.
....	....	....	....	S. H. Miller.
....	....	Towards $5\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	G. Plummer.
train or sparks	12°	....	....	W. C. Nash.
rain remained 8° in ngth.	....	....	....	T. Crumplen.
a train	....	....	....	A. S. Herschel.
....	....	Towards 3 hour of a watch-face held with 12^h vertical.	....	James Challis.
a luminous train......	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	G. Plummer.
no train, but illuminted the heavens conderably.	....	From Cassiopeia	Probably brighter at the commencement of the track which was not seen.	W. De la Rue.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 10 15 48 p.m.	Wisbech (Cambridgeshire).	Bright; = to 2nd mag.*.	....	½ second	From head of ‹ pheus to ι Cyg
10	10 16 p.m.	Weston-super-Mare.	=to Sirius	White	0·5 second ...	From 1 and 2 ‹ melopardali t‹ Aurigæ.
10	10 16 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	From ½ (ι, κ) Cy to ε Lyræ(centr and 12° beyond
10	10 16 14 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced 3‹ W. from S., a‹ tude 42°·5.
10	10 16 30 p.m.	Hampton (Middlesex).	=1st mag.*	....	....	From ½ (O, P) ‹ melopardali t‹ Ursæ Majoris.
10	10 17 p.m.	Euston Road (London).	=1st mag.*	Ruddy and white.	1 second	From ½ (α Delph γ Sagittæ) to‹ Aquilæ, and further.
10	10 17 9 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 1‹ W. from S.
10	10 17 14 p.m.	Ibid	=3rd mag.*	....	....	Commenced 3‹ W. from S., a‹ tude 51°.
10	10 17 15 p.m.	Hawkhurst (Kent).	>than Jupiter ...	Orange colour	1·3 second ...	From α Ursæ M‹ joris to ½° ove‹ Ursæ Majoris, ‹ 3° further.
10	10 18 p.m.	Greenwich Observatory.	=1st mag.*	Blue............	Less than 1 sec.	From Lacerta t‹ Cygni.
10	10 18 p.m.	Hampton (Middlesex).	Large meteor; >1st mag.*.	....	....	From ζ Cassiop‹ to ½ (d, ε) Peg
10	10 18 50 p.m.	Cranford Observatory.	Very brilliant meteor.	....	....	Appeared abov‹ Cygni; passed‹ tween γ, δ, cl‹ to χ, φ, β Cyg and several‹ grees beyond.
10	10 18 54 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 4° from S., alt. 5‹
10	10 19 p.m.	Hawkhurst (Kent).	=to Venus	White	1·5 second ...	From ½ (g, ζ) D‹ conis to a p‹ ⅘ of the way‹ wards β Hercu‹
10	10 19 p.m.	Euston Road (London).	Much > Venus ...	White	1·3 second ...	From a point ⅓ a point ⅔ of distance fr‹ κ Herculis t‹ Serpentis.
10	10 20 p.m.	Weston-super-Mare.	=2nd mag.*	Blue-white ...	1 second	From σ Herculis σ Bootis.
10	10 20 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	0·8 second ...	Centre at b Lyn‹
10	10 20 30 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced 2‹ W. from S., a‹ tude 47°.
10	10 20 45 p.m.	Cranford Observatory.	Bright meteor	....	....	From δ Ursæ M‹ joris below i‹ nes Venatici.

›earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
train or sparks	....	....	....	S. H. Miller.
n endured $1\frac{1}{2}$ second; hite.	....	....	....	W. H. Wood.
rain or sparks	....	....	....	A. S. Herschel.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
a short train	....	....	....	H. Temple Humphreys.
....	....	....	....	T. Crumplen.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	Time doubtful............	James Challis.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	Id.
livided into two parts; patch at χ Ursæ re- ined for 6 seconds.	....	....	....	A. S. Herschel.
in remained for 1 ond.	....	....	....	W. C. Nash.
h train for 3 or 4 onds.	....	....	....	H. Temple Humphreys.
t bright train visible several seconds.	....	....	....	W. De la Rue.
t luminous train for (	....	....	....	James Challis.
ain endured 3 secs.; h swollen in the ille.	....	....	Corresponds to Cranford, $10^h\ 18^m\ 50^s$ p.m.	A. S. Herschel.
e tiful meteor, emit- a brilliant light.	....	....	....	T. Crumplen.
t white train for 1 ond.	....	....	....	W. H. Wood.
rain for 2 seconds..	7°	From *b* Camelopardali...	....	A. S. Herschel.
ry stationary flash...	....	Towards 9 hour of a watch-face held with 12^h vertical.	....	James Challis.
....	....	....	....	W. De la Rue.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1863. Aug. 10	h m s 10 20 58 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 34 W. from S., tude 37°.
10	10 21 p.m.	Hawkhurst (Kent).	=1st mag.*	Yellow	1·2 second ...	To 3° unde Camelopard halfway fro Camelopard
10	10 21 8 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	From α Ceph α Cygni.
10	10 22 43 p.m.	Ibid	=3rd mag.*	....	....	Commenced W. from S., tude 43°·5.
10	10 23 p.m.	Greenwich Observatory.	=3rd mag.*	Blue	Less than 1 sec.	Between Aries Pegasus.
10	10 25 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	0·5 second ...	From β Bootis Serpentis.
10	10 25 22 p.m.	Cranford Observatory.	=2nd mag.*	....	....	From ε to α B
10	10 25 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	0·8 second ...	On a line δ Ursæ to Caroli. Fro to 14° be the latter st
10	10 26 p.m.	Weston-super-Mare.	=1st mag.*.........	White, then red.	0·5 second ...	From head of Major to the of Lynx.
10	10 27 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	0·5 second ...	From Cor Car
10	10 27 30 p.m.	Cranford Observatory.	=2nd mag.*	....	Motion extremely slow.	One degree l κ, ι Ophiuch extensive those stars.
10	10 28 16 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced W. from S. tude 49°·5.
10	10 28 49 p.m.	Ibid	=2nd mag.*	....	....	Commenced 2 W. from S. tude 21°·5.
10	10 29 p.m.	Weston-super-Mare.	>1st mag *	Yellow	1 second	From γ Boot α Bootis.
10	10 29 17 p.m.	Cambridge Observatory.	....	....	....	....
10	10 29 25 p.m.	Cranford Observatory.	=2nd mag.*	....	....	From ε beyo Lyncis.
10	10 29 56 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced W. from S., tude 55°·5.
10	10 30 45 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	....	To 1° over χ Majoris; ⅓ way from α Majoris.
10	10 30 47 p.m.	Cambridge Observatory.	....	....	....	Commenced W. from S., tude 18°.

…pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…t a luminous train......	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
…: a train for 2 seconds	....	....	....	A. S. Herschel.
… a luminous train......	....	....	....	J. C. Adams.
....	....	Towards 9 hour of a watch-face held with 12^h vertical.	....	James Challis.
… small meteors pur-…ed parallel courses.	....	.... 	In a space between Aries and Pegasus, devoid of large stars.	W. C. Nash.
… a train for 1 second...	....	....	....	W. H. Wood.
....	....	....	....	W. De la Rue.
....	....	....	....	A. S. Herschel.
…a train	....	....	....	W. H. Wood.
....	12°	25° to left of perpendicular; down.	....	Id.
…ain or sparks	....	Parallel to κ, ι Ophiuchi	....	W. De la Rue.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
…: short train	....	Towards $5\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	....	James Challis.
…: white train	....	....	....	W. H. Wood.
…dinary shooting-star	....	....	....	....
....	....	....	....	W. De la Rue.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
…train for 1 second...	....	....	....	A. S. Herschel.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1863. Aug. 10	h m s 10 31 30 p.m.	Hawkhurst (Kent).	=1st mag.*	White	1 second	From $\frac{1}{3}$ (ϵ,ν) C $\frac{4}{5}$ of the wa α Aquilæ.
10	10 31 32 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced W. from S., tude 57°.
10	10 31 57 p.m.	Ibid	=2nd mag.*	....	....	Commenced W. from S., tude 30°·5.
10	10 32 28 p.m.	Wisbech (Cambridgeshire).	=1st mag.*	....	$2\frac{1}{4}$ seconds	From $\frac{1}{2}$ (η Minoris, ψ conis) to $\frac{1}{2}$ (Bootis.
10	10 33 18 p.m.	Ibid	=3rd mag.*	....	....	From τ to ι conis.
10	10 33 25 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced W. from S., tude 37°·5.
10	10 33 29 p.m.	Ibid	=2nd mag.*	....	....	Commenced W. from S., tude 45°·5.
10	10 34 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·8 second	To ι Herculis 5° further, way from τ conis.
10	10 34 p.m.	Greenwich Observatory.	=1st mag.*	Blue	1 second	α Cygni to β C
10	10 35 p.m.	Ibid	=1st mag.*	Blue	1 second	From δ Aquil the horizon.
10	10 36 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	....	From 10° to beyond Arc on a line fr Ursæ Major
10	10 36 45 p.m.	Ibid	=2nd mag.*	....	....	From α Dracor θ Bootis an further.
10	10 36 55 p.m.	Cambridge Observatory.	....	....	....	....
10	10 37 1 p.m.	Ibid	=3rd mag.*	....	....	Commenced 2 W. from S., tude 55°·5.
10	10 37 5 p.m.	Wisbech (Cambridgeshire).	Bright meteor, = 2nd mag.*.	....	....	From n Tarran O Camelopar
10	10 37 55 p.m.	Cambridge Observatory.	=2nd or 3rd mag.*	....	....	Commenced W. from S., tude 29°·5.
10	10 38 15 p.m.	Wisbech (Cambridgeshire).	=1st mag.*	....	....	From $\frac{1}{3}$ (N, Q) melopardali Ursæ Majori
10	10 39 4 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 4 W. from S., tude 31°·5.
10	10 39 20 p.m.	Greenwich Observatory.	=2nd mag.*	Blue	Less than 1 sec.	From α Corona wards the horizon.

pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
t a train for 2 seconds	....	....	....	A. S. Herschel.
....	....	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	....	....	S. H. Miller.
....	....	....	....	Id.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	Id.
a fine faint train for second.	....	....	Corresponds to Cambridge, 10^h 33^m 29^s p.m.	A. S. Herschel.
a luminous streak ...	22°	....	....	W. C. Nash.
a luminous streak ...	25°	....	....	Id.
rain or sparks	....	....	....	A. S. Herschel.
a train for 1 second...	....	....	....	Id.
ting-star of ordinary pearance.	....	....	....	....
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	....	....	S. H. Miller.
....	....	Towards $4\frac{1}{4}$ hour of a watch-face held with 12^h vertical.	....	James Challis.
....	....	....	....	S. H. Miller.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	....
a luminous train	20°	....  30° from horizontal.	....	W. C. Nash.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 10 39 40 p.m.	Greenwich Observatory.	=2nd mag.*	Bluish white...	1 second	On a line through α Herculis fro a point below α
10	10 39 47 p.m.	Cambridge Observatory.	....	....	....	Commenced 28 W. from S., altitude 30°·5.
10	10 40 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·5 second ...	From ψ to ½ (ι, Cephei.
10	10 40 20 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 32 W. from S., altitude 46°.
10	10 41 p.m.	Southsea (Portsmouth).	=3rd mag.*	White	1½ second ...	From β Equu to ½ (κ Antin α Capricorni).
10	10 41 24 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced 94 W. from S., altitude 55°.
10	10 41 30 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	....	From ρ to ε Coron and as far agai
10	10 41 30 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced 41 W. from S., altitude 41°·5.
10	10 41 40 p.m.	Ibid	=3rd mag.*	....	....	Commenced 27 W. from S., altitude 32°·5.
10	10 42 30 p.m.	Greenwich Observatory.	=2nd mag.*	Blue	1 second	From ε Ophiu towards the horizon.
10	10 42 50 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 10 W. from S., altitude 52°·5.
10	10 43 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	Red	1 second	On a line from Ursæ Majoris Arcturus, fro 7° to 12° beyo the latter star.
10	10 44 p.m	Wisbech (Cambridgeshire).	Bright meteor; > 1st mag.*.	Deep blue ...	1½ second ...	From γ, halfway ζ Bootis.
10	10 45 p.m.	Fairlight (Hastings).	Large meteor. Flash of diffused light.	White, then red.	3 seconds......	From α Aquilæ, ha way between Antinoï towar the horizon.
10	10 45 45 p.m.	Hawkhurst (Kent).	Meteor = to 3 × Venus.	'Mauve' - colour.	2 seconds......	From ½ (θ Aquil ε Delphini) to (α Capricorni, Antinoï), and further.
10	10 46 4 p.m.	Cambridge Observatory.	=1st mag.*.........	....	....	Commenced 34 W. from S., altitude 73°.
10	10 46 46 p.m.	Ibid	=1st mag.*.........	....	....	Appeared 233°·5 from S., alt. 38
10	10 47 p.m.	Hawkhurst (Kent).	Last 5° > Venus	Yellow	1½ second ...	To 1° above d Camelopardali a 5° further, hal way from α Pers

...arance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	12°	Towards W. horizon ...	....	W. C. Nash.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
a luminous train; ...adest in the middle.	....	....	Corresponds to Cambridge, $10^h 40^m 20^s$ p.m.	A. S. Herschel.
a luminous train ...	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	....	....	W. Penn.
....	....	Towards 7½ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...ain or sparks	....	....	Corresponds to Cambridge, $10^h 41^m 30^s$ p.m.	A. S. Herschel.
....	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	James Challis.
...ain or sparks	30°	....  30° from horizontal.	....	W. C. Nash.
....	....	Towards 4½ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
...ain or sparks. Dis-...eared behind clouds.	....	....	A flash of lightning in the same quarter of the horizon.	A. S. Herschel.
...a train for several ...onds, coruscant.	....	....	....	S. H. Miller.
...lar, leaving a perma-...t train; afterwards ...ɔ-shaped, with a ...rt adhering tail.	....	Down the eastern edge of the Milky Way.	A permanent patch of light remained 5° or 10°, onwards from ι, λ Antinoï.	James Rock, Jun.
... streak 5 seconds. ...ch 45 seconds.	....	....	A luminous patch remained 45 seconds in the last 7° of the visible track.	A. S. Herschel.
... luminous train ...	....	Towards 4¼ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
... bright stationary ...n.	....	....	....	James Challis.
...: last 5° left a patch ...ght for 30 seconds.	....	....	Train composed of a streak and a patch. Corresponds to Cambridge, $10^h 46^m 46^s$ p.m.	J.F.W. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 10 47 p.m.	Hampton (Middlesex).	=to Venus	... .	....	From ε And... medæ to ½ (α ... Pegasi.
10	10 47 20 p.m.	Wisbech (Cambridgeshire).	=to Jupiter	Very blue......	1 second	From ⅓ (η to... to ½ (α, ... Persei.
10	10 48 p.m.	Greenwich Observatory.	=3rd mag.*	Blue	½ second	From Camelo... dalus to α U... Majoris.
10	10 48 p.m.	Euston Road (London).	Brighter than Venus	....	1·5 second ...	From near κ Aqu... to near α Ca... corni.
10	10 48 29 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced ... W. from S., ... tude 23°·5.
10	10 48 39 p.m.	Ibid	=3rd mag.*	....	....	Commenced 34 ... W. from S., ... tude 30°.
10	10 50 25 p.m.	Wisbech (Cambridgeshire).	=1st mag.*	....	2 seconds......	From ½ (η U... Majoris, θ Bo... to γ Bootis.
10	10 51 45 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced ... W. from S., ... tude 21°.
10	10 52 p.m.	Weston-super-Mare.	Bolide 6 × as bright as Venus.	Varicoloured	3 seconds......	From π Cassio... to α Caprico...
10	10 52 26 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced 3... W. from S., ... tude 67°·5.
10	10 52 30 p.m.	Hawkhurst (Kent).	=1st mag.*	White	....	From 4° belo... Ursæ Minori... ½ (ι, α) Drac... and half as... again.
10	10 56 p.m.	Ibid	=3rd mag.*	White	....	From ε Ursæ ... joris to ⅓ (... Can. Vena... rum.
10	10 56 1 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced ... W. from S., ... tude 42°.
10	10 56 38 p.m.	Ibid	=3rd mag.*	....	....	Commenced ... W. from S., ... tude 25°·5.
10	10 57 p.m.	Greenwich Observatory.	=2nd mag.*	Blue	1 second	From a point b... α Draconis ... Bootis.
10	10 57 p.m.	Wisbech (Cambridgeshire).	=1st mag.*.........	....	....	From κ Cassio... to η Ursæ ... noris.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
...t a train for a few ...econds.	....	....	....	H. Temple Humphreys.
...uscant. Left a train ...r several seconds.	....	....	....	S. H. Miller.
... a slight train	About 25°...	....	....	W. C. Nash.
... streak remained upon ...e whole length of ...e path. Near the ...d it was seen four-...d-a-half minutes in ... opera-glass, curling ... and fading gradu-...ly from each ex-...emity.	....	....	For a drawing of the luminous streak, see Appendix.	T. Crumplen.
... a luminous train......	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	Id.
...it train	....	....	....	S. H. Miller.
....	....	Towards $3\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
...ppeared with vari-...loured sparks. Left ... prismatic-coloured ...l of great dura-...n.	....	....	....	W. H. Wood.
....	....	Towards $5\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...a train for 2 seconds	....	....	Corresponds to Cambridge, 10^h 52^m 26^s p.m.	A. S. Herschel.
...a train for $\frac{1}{2}$ second...	....	....	....	Id.
....	....	Towards $3\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	....	James Challis.
....	....	Towards $3\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
.... train	25°	....	....	W. C. Nash.
...t small train	....	....	....	S. H. Miller.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug.10	h m s 10 57 30 p.m.	Hawkhurst (Kent).	>1st mag.*	Red	1·5 sec.; slow	On a line fro[m] Aquarii thr[o] (δ, γ) Capric[orni] to the horiz[on]
10	10 58 p.m.	Ibid	=1st mag.*	White	1 second	From ½ (α, ζ) P[e] towards ζ A[qua]rii.
10	10 58 p.m.	Ibid	=1st mag.*	White	1 second	From β Cephei [to] Cygni.
10	10 58 p.m.	Ibid	=1st mag.*	White	1 second	From α to β Cy[gni]
10	10 58 2 p.m.	Cambridge Observatory.	....	....	....	Commenced 31 W. from S., [alti]tude 33°.
10	10 58 5 p.m.	Ibid	=2nd mag.*	....	....	Commenced W. from S., [alti]tude 43°.
10	10 58 5 p.m.	Ibid	=3rd mag.*	....	....	Commenced W. from S., [alti]tude 42°·5.
10	10 59 p.m.	Greenwich Observatory.	=1st mag.*	Blue	1 second	From near α P[e]
10	11 0 22 p.m.	Cambridge Observatory.	....	....	....	Commenced W. from S., [alti]tude 53°·5.
10	11 0 27 p.m.	Ibid	....	....	....	....
10	11 1 12 p.m.	Ibid	=1st or 2nd mag.*	....	....	Commenced W. from S., [alti]tude 36°·5.
10	11 1 24 p.m.	Ibid...............	=2nd mag.*	....	....	Commenced W. from S., [alti]tude 13½°.
10	11 1 54 p.m.	Ibid...............	=3rd mag.*	....	....	Commenced 3[0] W. from S., [alti]tude 31°·5.
10	11 2 p.m.	Hawkhurst (Kent).	=1st mag.*	White	1 second	From 3° over [α An]dromedæ.
10	11 2 2 p.m.	Wisbech (Cambridgeshire).	=1st mag.*	....	2 seconds......	From α Cephe[i to] Herculis.
10	11 2 2 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced W. from S., [alti]tude 27°.
10	11 3 27 p.m.	Ibid	=2nd mag.*	....	....	Commenced W. from S., [alti]tude 36°.
10	11 3 37 p.m.	Ibid	=2nd mag.*	....	....	Commenced 2[?] W. from S., [alti]tude 29°·5.
10	11 3 30 p.m.	Hawkhurst (Kent).	=1st mag.*	White	1 second	From κ Cassi[opeiæ] to ½ (β C[assio]peiæ, δ Cep[hei])
10	11 3 47 p.m.	Cambridge Observatory.	=3rd mag.*	....	....	Commenced W. from S., [alti]tude 34°·5.
10	11 4 16 p.m.	Ibid	=2nd or 3rd mag.*	....	....	Commenced W. from S., [alti]tude 43°·5.
10	11 4 26 p.m.	Ibid	....	....	....	....

…arance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…il visible in haze of … horizon.	8° or 10°…	…………	Disappeared behind the horizon.	A. S. Herschel.
… tail for 2 seconds…	…………	…………	Three bright meteors appeared almost together.	Id.
… tail for 2 seconds…	…………	…………	Positions somewhat uncertain.	Id.
… train for 2 seconds	…………	…………	…………	Id.
…………	…………	Towards 4 hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
…………	…………	Towards 4 hour of a watch-face held with 12^h vertical.	…………	James Challis.
…………	…………	Towards 5 hour of a watch-face held with 12^h vertical.	…………	Id.
…a train for a few …ends.	…………	Inclined path in the S. Moving westerly.	Cloudy in S. …………	W. C. Nash.
…………	…………	Towards 4 hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
…ng-star of ordinary …arance.	…………	…………	…………	James Challis.
… luminous train……	…………	Towards $3\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
…………	…………	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	…………	J. C. Adams.
…………	…………	Towards $4\frac{1}{4}$ hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
… train for $2\frac{1}{2}$ seconds	18° ………	Towards γ Piscium……	…………	A. S. Herschel.
…train …………	…………	…………	…………	S. H. Miller.
…………	…………	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	…………	James Challis.
…………	…………	Towards 3 hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
…………	…………	Towards 5 hour of a watch-face held with 12^h vertical.	…………	James Challis.
…rain for 3 seconds	…………	…………	…………	A. S. Herschel.
…………	…………	Towards $3\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	…………	J. Plummer.
…………	…………	Towards $3\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	…………	James Challis.
…g-star of ordinary …rance.	…………	…………	…………	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 11 4 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	Appeared at o cium.
10	11 4 30 p.m.	Greenwich Observatory.	=3rd mag.*	Blue	1 second	Centre at α Peg
10	11 5 6 p.m.	Cambridge Observatory.	=1st mag.*.........	....	....	Commenced 1 W. from S., tude 10°·5.
10	11 6 26 p.m.	Ibid	=2nd mag.*	....	....	Commenced 1 W. from S., tude 29°·5.
10	11 6 30 p.m.	Hawkhurst (Kent).	=to Venus	Orange.........	About 1 sec....	From ϵ Aquilæ Serpentis.
10	11 7 1 p.m.	Cambridge Observatory.	=1st or 2nd mag.*	....	....	Commenced 52 from S., altit 28°·5.
10	11 7 p.m.	Hawkhurst (Kent).	=to Sirius	Yellow	About 1 sec....	To δ Serpentis, the way fror Coronæ.
10	11 7 p.m.	Greenwich Observatory.	=1st mag.*.........	Blue	1 second	From α Aquila within about of the horizo
10	11 8 p.m.	Southsea (Portsmouth).	Rather > than 1st mag.*.	Yellow	1 second	From (ι, κ) Andromedæ to ½ (α Pegasi, and sev degrees furthe
10	11 8 p.m.	Hawkhurst (Kent).	=to Sirius	Yellow	1 second	From ½ (ι Herc α Lyræ) thro ξ Herculis to short of α O uchi.
10	11 8 18 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 1 W. from S., tude 29°·5.
10	11 8 23 p.m.	Ibid	=1st or 2nd mag.*	....	....	Commenced W. from S., tude 29°.
10	11 9 p.m.	Greenwich Observatory.	=1st mag.*; very brilliant.	Blue............	1½ second ...	From γ Cygni, ac β Cygni an Aquilæ tow the W. horiz
10	11 10 59 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 48 from S., altit 27°.
10	11 10 59 p.m.	Ibid	=2nd mag.*	....	....	Commenced 75 from S., altit 21°·5.
10	11 11 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	0·8 second ...	From μ Drac to π Herc and 6° furthe
10	11 11 p.m.	Ibid	=2nd mag.*	....	0·8 second ...	Centre 2° ove Ursæ Majoris
10	11 11 30 p.m.	Greenwich Observatory.	=2nd mag.*	Blue............	1 second	To γ Herculis, f λ Lyræ.
10	11 11 57 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 1 W. from S., tude 28°.
10	11 14 p.m.	Southsea (Portsmouth).	Large meteor	....	½ second ...	Across β Cassio towards β Peg

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
…rain or sparks ………	10° ………	Directed from γ Andromedæ.	………………………	A. S. Herschel.
… a faint train ………	15° ………	From Cassiopeia ………	………………………	W. C. Nash.
………………………	……………	Towards 8 hour of a watch-face held with 12^h vertical.	………………………	J. C. Adams.
………………………	……………	Towards 8 hour of a watch-face held with 12^h vertical.	………………………	Id.
… tail endured two …conds in the last half … the course.	……………	………………………	………………………	A. S. Herschel.
…a luminous train……	……………	Towards 7 hour of a watch-face held with 12^h vertical.	………………………	J. Plummer.
…a train for 2 seconds	……………	………………………	Corresponds to Cambridge, 11^h 7^m 1^s p.m.	A. S. Herschel.
…a fine train ………	30° ………	………………………	………………………	W. C. Nash.
…a train ………	……………	………………………	………………………	W. Penn.
…a train for 2 seconds	……………	………………………	The head continued beyond the streak. Corresponds to Greenwich, 11^h 9^m p.m.	A. S. Herschel.
………………………	……………	………………………	………………………	J. C. Adams.
… luminous train……	……………	Towards $3\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	………………………	J. Plummer.
… fine train for 2 or 3 …onds.	50° ………	………………………	………………………	W. C. Nash.
………………………	……………	Towards 5 hour of a watch-face held with 12^h vertical.	………………………	J. Plummer.
………………………	……………	Towards 7 hour of a watch-face held with 12^h vertical.	………………………	J. C. Adams.
…in or sparks ………	……………	………………………	………………………	A. S. Herschel.
…in or sparks ………	6°………	From β Camelopardali..	………………………	Id.
…rain for $1\frac{1}{2}$ second…	35° ………	………………………	………………………	W. C. Nash.
………………………	……………	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	………………………	James Challis.
…rain ………	……………	………………………	………………………	W. Penn.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1863. Aug. 10	h m s 11 14 40 p.m.	Cambridge Observatory.	= 2nd mag.*	......	......	Commenced W. from S., tude 57°.
10	11 14 45 p.m.	Ibid	= 2nd mag.*	......	......	Commenced W. from S., tude 46°·5.
10	11 15 p.m.	Greenwich Observatory.	= 1st mag.*	Blue	1 second	From Cephe across δ Cyg
10	11 15 25 p.m.	Cambridge Observatory.	= 2nd mag.*	......	......	Commenced W. from S., tude 49°·5.
10	11 15 45 p.m.	Ibid	......	......	......	......
10	11 16 p.m.	Southsea (Portsmouth).	Large meteor	......	......	Across γ Trian
10	11 16 5 p.m.	Cambridge Observatory.	= 1st mag.*	......	......	Commenced 7(from S., alt 19°.
10	11 17 p.m.	Hawkhurst (Kent).	= 2nd mag.*	......	½ second	From ψ to ζ conis.
10	11 17 30 p.m.	Ibid	= to Venus	......	......	From head of pheus to 1° γ Cygni.
10	11 17 34 p.m.	Cambridge Observatory.	= 2nd mag.*	......	......	Commenced W. from S., tude 26°·5.
10	11 18 p.m.	Southsea (Portsmouth).	Large meteor	......	......	......
10	11 18 45 p.m.	Hawkhurst (Kent).	= 1st mag.*	......	......	From 2° E. Cygni to 4° γ Delphini.
10	11 19 24 p.m.	Cambridge Observatory.	= 2nd or 3rd mag.*	......	......	......
10	11 19 54 p.m.	Ibid	= 2nd mag.*	......	......	Commenced 5(from S., alt 46°·5.
10	11 20 p.m.	Weston-super-Mare.	= to Venus	Bright yellow	2·5 seconds	From 76 Majoris to (ronæ.
10	11 20 30 p.m.	Hawkhurst (Kent).	= to Venus	......	1 second	From γ, ξ Ca peiæ to 1° E ι Andromedæ ⅔ as far again
10	11 21 p.m.	Weston-super-Mare.	= to Jupiter	Yellow, then red.	2 seconds	From 76 Majoris to (ronæ.
10	11 21 p.m.	Ibid	= to Jupiter	Ruddy	2 seconds	From δ Ursæ joris to ξ Bo
10	11 21 to 11 23 p.m.	Ibid	= 1st and 2nd mag.*	......	......	From R. A. N. Decl. towards the
10	11 21 29 p.m.	Cambridge Observatory.	= 1st mag.*	......	......	Commenced W. from S., tude 25°.
10	11 22 p.m.	Weston-super-Mare.	= to Sirius	White	2 seconds	From η Ursæ joris to α Bo
10	11 22 43 p.m.	Cambridge Observatory.	= 3rd mag.*	......	......	Commenced 4(from S., alt 25°·5.

...pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	Towards $4\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	Towards 8 hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...t a train for 2 seconds	23°	....	....	W. C. Nash.
....	....	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...oting-star of ordinary ...ppearance.	....	....	....	James Challis.
....	....	Towards θ Persei	....	W. Penn.
....	....	Towards 7 or 8 hour of a watch-face held with 12^h vertical.	....	James Challis.
...train or sparks	6°........	....	....	A. S. Herschel.
...a train for 3 seconds	....	....	....	Id.
....	....	Towards 8 hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
...e a tail	....	....	....	W. Penn.
....	....	....	....	A. S. Herschel.
....	....	Towards 6^h of a watch-face held with 12^h vert.	....	....
....	....	Towards 6 hour of a watch-face held with 12^h vertical.	....	....
...ddy train remained ...on the whole course ...seconds.	....	....	Clouds breaking off, and sky clearing.	W. H. Wood.
...train, in two parts, ...mained 5 seconds.	....	....	....	A. S. Herschel.
...y train remained ...on the whole path ...3econds.	....	....	The succeeding meteors followed closely one upon another.	W. H. Wood.
...y train upon the ...vole course 3 seconds.	....	....	....	Id.
...trains. Eight or ten ...s...oting-stars per mi...n...e.	10° to 30°..	Taking westerly paths...	A number of shooting-stars.	Id.
...luminous train......	....	Towards 8 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
...ruddy train	....	....	....	W. H. Wood.
....	....	Towards 6 hour of a watch-face held with 12^h vertical.	....	J. Plummer.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 11 23 p.m.	Weston-super-Mare.	= to Sirius	White	1·5 second ...	From γ Bootis
10	11 23 p.m.	Ibid	= to Sirius	Ruddy	1·5 second ...	From β Bootis, low α Bootis.
10	11 23 p.m.	Ibid	= 1st and 2nd mag.*	....	....	From the upper parts of Boot
10	11 23 p.m.	Southsea (Portsmouth).	Meteor = to Venus	White	1 second ...	From 3° belo Andromedæ (δ Andromed Pegasi).
10	11 23 30 p.m.	Hawkhurst (Kent).	= 1st mag.*	....	1 second ...	From ι An medæ, acros Pegasi to ½ (Pegasi.
10	11 24 3 p.m.	Cambridge Observatory.	= 3rd mag.*	....	....	Commenced 6 W. from S., tude 27°·5.
10	11 24 10 p.m.	Ibid	= 2nd mag.*	....	....	Commenced W. from S., tude 53°·5.
10	11 24 17 p.m.	Ibid	....	....	....	Commenced W. from S., tude 52°·5.
10	11 24 18 p.m.	Ibid	....	....	....	....
10	11 25 53 p.m.	Ibid	= 1st mag.*	....	....	Commenced W. from S., tude 64°.
10	11 26 23 p.m.	Ibid	= 1st mag.*	....	....	Commenced W. from S., tude 50°·5.
10	11 26 30 p.m.	Hawkhurst (Kent).	= 2nd mag.*	Yellow	....	From 4° left Ursæ Major ½ (α, β) Majoris.
10	11 27 47 p.m.	Cambridge Observatory.	= 2nd mag.*	....	....	Commenced W. from S., tude 16°·5.
10	11 28 p.m.	Weston-super-Mare.	= to Sirius	White	1·5 second ...	From γ Bootis.
10	11 28 p.m.	Southsea (Portsmouth).	= 2nd mag.*	....	¼ second ...	From α to β A
10	11 28 p.m.	Ibid	= 2nd mag.*	....	¼ second ...	From β Cassio to β Androm
10	11 28 8 p.m.	Cambridge Observatory.	....	....	....	....
10	11 28 43 p.m.	Ibid	= 1st mag.*	....	....	Position not corded.
10	11 29 p.m.	Southsea (Portsmouth).	= 2nd mag.*	....	½ second ...	From α Arieti Menkar.
10	11 29 30 p.m.	Hawkhurst (Kent).	= 1½ mag.*	....	....	From 1° unde to η Androm

…arance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
train 25° long	......	30° to left of perpendicular. 	Two meteors appeared together.	W. H. Wood.
......	......	......	......	Id.
rains	......	......	A number of shooting-stars.	Id.
feathery train	......	Towards θ Piscium......	......	W. Penn.
train for 2 seconds	......	......	......	A. S. Herschel.
......	......	Towards 6 hour of a watch-face held with 12^h vertical.	......	J. Plummer.
uminous train	......	Towards $8\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	......	J. C. Adams.
......	......	Towards $8\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	......	J. Plummer.
g-star of ordinary rance.	......	......	......	James Challis.
......	......	Towards 9 hour of a watch-face held with 12^h vertical.	......	J. C. Adams.
......	......	Towards 3 hour of a watch-face held with 12^h vertical.	......	J. Plummer.
a or sparks	......	......	......	A. S. Herschel.
......	......	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	......	J. C. Adams.
2' long	25°	30° left of perpendicular. 	......	W. H. Wood.
......	......	......	......	W. Penn.
......	......	......	......	Id.
n star of ordinary ance.	......	......	......	James Challis.
inous train......	......	......	......	J. C. Adams.
......	......	......	......	W. Penn.
n for 1 second...	......	......	......	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, o Altitude an Azimuth.
1863. Aug. 10	h m s 11 30 8 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced W. from S. tude 27·5.
10	11 30 17 p.m.	Ibid	=2nd mag.*	....	....	Commenced 7 from S., al 38°.
10	11 31 p.m.	Weston-super-Mare.	> 1st mag.*	White	1 second	Between (α,β Majoris.
10	11 31 p.m.	Southsea (Portsmouth).	=1½ mag.*	White	½ second	β Cassiopeiæ Pegasi.
10	11 32 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·8 second	From α to β A
10	11 32 15 p.m.	Ibid	=2nd mag.*	Orange colour	0·8 second	From ⅓ (δ, β Aurigæ.
10	11 33 49 p.m.	Cambridge Observatory.	=2nd mag.*	....	....	Commenced 4 from S., al 45°·5.
10	11 34 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	1 second	From δ Ursa joris.
10	11 34 p.m.	Southsea (Portsmouth).	=1½ mag.*	White	½ second	From β Cassi to μ Pegas
10	11 36 p.m.	Weston-super-Mare.	=Sirius	White	1 second	Appeared cl Mizar.
10	11 38 p.m.	Ibid	>1st mag.*	White	....	Appeared du altitude 12° the horizon.
10	11 38 p.m.	Southsea (Portsmouth).	....	....	1 second	α Arietis to M
10	11 39 p.m.	Ibid	....	White	1½ second	Across (ι, κ dromedæ.
10	11 40 p.m.	Weston-super-Mare.	>1st mag.*	White	1 second	From β past ε
10	11 40 to 11 43 p.m.	Ibid	= to 1st, 2nd, and 3rd mag.*.	....	....	From β Boot
10	11 45 15 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	0·7 second	From P Ca pardali to Draconis.
10	11 45 45 p.m.	Ibid	=3½ mag.*	....	0·8 second	Commencem B Camelop
10	11 46 52 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced W. from S tude 36°.
10	11 46 p.m.	Southsea (Portsmouth).	Large meteor, >1st mag.*.	White	1½ second	From ζ Aqu Fomalhaut
10	11 46 p.m.	Weston-super-Mare.	= to Sirius	White	1 second	From β Boot Coronæ.
10	11 47 39 p.m.	Cambridge Observatory.	....	....	....	Commenced from S., a 51°.
10	11 48 p.m.	Weston-super-Mare.	=1st mag.*	Ruddy	0·5 second	From γ Urs noris to conis.
10	11 48 p.m.	Southsea (Portsmouth).	=2½ mag.*	White	½ second	θ Piscium Aquarii.
10	11 48 4 p.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced N.W. of α

...earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
a luminous train	....	Towards 8 hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
....	....	Towards $5\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
a train 12° long	12°	60° left of perpendicular down.	....	W. H. Wood.
....	....	....	....	W. Penn.
train	....	....	....	A. S. Herschel.
rain or sparks	....	....	....	Id.
....	....	Towards 5 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
ain or sparks	15°	20° left of perpendicular down.	....	W. H. Wood.
train	....	....	....	W. Penn.
upon whole length ...he course.	....	40° to left of perpendicular down.	....	W. H. Wood.
train	....	Almost vertically down	....	Id.
....	....	....	....	W. Penn.
....	20°	Towards *h* Pegasi	....	Id.
luminous streak ...	....	....	....	W. H. Wood.
rains	....	....	Several shooting-stars in quick succession.	Id.
train for 0·6 second	....	....	....	A. S. Herschel.
train for 1 second...	2°...........	Directed from γ Persei..	....	Id.
uminous train	....	Towards 8 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
long train, wide at ...art, like a dash with ...ll pen.	....	....	....	W. Penn.
white train	....	....	....	W. H. Wood.
...g-star of ordinary ...rance.	....	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
...uddy tail	....	....	....	W. H. Wood.
... or sparks	....	....	....	W. Penn.
...minous train	....	....	....	J. Plummer.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 10	h m s 11 48 51 p.m.	Cambridge Observatory.	....	....	....	Through Cassio
10	11 49 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·7 second ...	From L Cam pardali halfw. π Ursæ Majo
10	11 50 p.m.	Southsea (Portsmouth).	=1½ mag.*	White	½ second	From β Andron to ζ Pegasi.
10	11 50 19 p.m.	Cambridge Observatory.	=1st or 2nd mag.*	....	....	Commenced 44 from S., alti 21°.
10	11 51 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	0·6 second ...	From o Cygn ½ (α Lyra Cygni).
10	11 52 45 p.m.	Ibid	=1st mag.*	....	0·8 second ...	From ½ (β, υ) (α, ζ) Pegas
10	11 54 30 p.m.	Ibid	=1½ mag.*	....	....	From β Cassio almost to g certæ.
10	11 55 p.m.	Weston-super-Mare.	=1st mag.*	Blue, white....	1 second	From Polaris
10	11 55 18 p.m.	Cambridge Observatory.	....	....	....	Commenced 3 W. from S., tude 46°·5.
10	11 55 53 p.m.	Ibid	=2nd mag.*	....	....	Commenced W. from S., tude 54°·5.
10	11 57 15 p.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	From 2° ov Herculis Herculis.
10	11 58 28 p.m.	Cambridge Observatory.	=1st or 2nd mag.*	....	....	Commenced W. from S. tude 46°.
10	12 0 p.m.	Hawkhurst (Kent).	=2nd mag.*	Yellow	0·8 second ...	From β Cassi 5° towar Lacertæ.
11	0 0 27 a.m.	Cambridge Observatory.	=1st or 2nd mag.*	....	....	From 284° W S., altitude
11	0 1 a.m.	Hawkhurst (Kent).	=2nd mag.*	....	....	To ½ (τ, υ) He halfway fi Draconis, a further.
11	0 1 2 a.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced from S., al 48°.
11	0 1 30 a.m.	Hawkhurst (Kent).	= α Lyræ	....	....	Passed midw tween ζ, e He ⅓ of the wa ξ Draconi on as far line (α Opl α Herculis
11	0 2 12 a.m.	Cambridge Observatory.	=1st mag.*	....	....	Commenced from S., a 64°.

pearance ; Train, if any, and its Duration.	Length of Path.	Direction ; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
oting-star of ordinary ppearance.	....	Towards 12 hour of a watch-face held with 12^h vertical.	....	J. C. Adams.
a train for 2 seconds..	....	....	....	A. S. Herschel.
a train	....	....	....	W. Penn.
a luminous train......	....	Towards $6\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	....	....	A. S. Herschel.
a train for 2 seconds..	....	....	....	Id.
a train for 2 seconds..	....	....	....	Id.
....	30°	In a westerly course ...	....	W. H. Wood.
....	....	Towards 4 hour of a watch-face held with 12^h vertical.	....	J. Plummer.
....	....	....	....	Id.
a train for 1 second...	....	....	....	A. S. Herschel.
luminous train	....	Towards $7\frac{1}{2}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
train for 1 second...	5°............	Towards *g* Lacertæ......	....	A. S. Herschel.
luminous train	....	Towards $4\frac{1}{4}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
train for $\frac{1}{2}$ second...	....	....	....	A. S. Herschel.
a luminous train, h remained visible ome time.	....	....	....	J. Plummer.
train for 2 seconds..	....	....	....	A. S. Herschel.
uminous train	....	Towards $6\frac{3}{4}$ hour of a watch-face held with 12^h vertical.	....	J. Plummer.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 11	h m s 0 3 27 a.m.	Cambridge Observatory.	....	....	....	Commenced 2 W. from S., tude 26°.
11	0 6 11 a.m.	Ibid	= 1st mag.*	....	....	Commenced W. from S., tude 72°·5.
11	0 10 a.m.	Weston-super-Mare.	= to Sirius	Vivid blue ...	0·5 second ...	Started at ε Majoris.
11	0 10 56 a.m.	Cambridge Observatory.	= 2nd mag.*	....	....	Commenced W. from S., tude 49°.
11	0 11 26 a.m.	Ibid	= 2nd mag.*	....	....	Commenced 23 W. from S., tude 42°·5.
11	0 11 26 a.m.	Ibid	= 2nd or 3rd mag.*	....	....	Commenced W. from S., tude 35°·5.
11	0 15 57 a.m.	Ibid	= 1st mag.*	....	....	Commenced W. from S., tude 30°·5.
11	0 16 30 a.m.	Ibid	= 1st mag.*	....	....	Commenced W. from S., tude 17°.
11	0 19 14 a.m.	Ibid	= 1st or 2nd mag.*	....	....	Commenced W. from S., tude 48°·5.
11	0 20 a.m.	Weston-super-Mare.	= 1st mag.*	....	1 second	Started at δ Majoris.
11	0 20 4 a.m.	Cambridge Observatory.	= 2nd mag.*	....	....	Commenced W. from S., tude 44°·5.
11	0 20 7 a.m.	Ibid	= 1st or 2nd mag.*	....	....	Commenced W. from S., tude 10°·5.
11	0 26 a.m.	Weston-super-Mare.	= 1st mag.*	Red, then blue	1 second	From θ Cygni Herculis.
11	0 45 a.m.	Ibid	= to Jupiter	Bright yellow and red.	2 seconds ...	From ½ (β Cyg Aquilæ) to below η pentis.
11	0 47 a.m.	Ibid	= 1st mag.*	Bright blue ...	1 second	First appeare by E., at alt 8°.
11	0 50 a.m.	Ibid	= 1st mag.*	Bright blue ...	1 second	First appeare by E., at alt 12°.
11	9 49 p.m.	Ibid	= to Sirius	White	1 second	From α Bootis
11	9 55 p.m.	Ibid	= to Sirius; very brilliant.	Yellow	1·5 second ...	From ν to α A medæ.
11	9 55 30 p.m.	Ibid	= to Sirius; very brilliant.	Yellow	1·5 second ...	From ν to α A medæ.
11	9 57 p.m.	Ibid	= to Sirius; very brilliant.	Yellow	1·5 second ...	From θ Andro to α Pegasi.
11	10 1 p.m.	Ibid	> 1st mag.*	Yellow	1 second + ...	From Cor Ca
11	10 8 30 p.m.	Hawkhurst (Kent).	= 2½ mag.*	White	0·9 second ...	Centre 2° ab Ursæ Majo

…pearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	Towards 5½ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
… a luminous train ...	....	Towards 12 hour of a watch-face held with 12^h vertical.	....	Id.
....	4°...........	30° left of perpendicular down.	....	W. H. Wood.
....	....	Towards 3½ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
e a luminous train	....	....	....	Id.
....	....	Towards 6 hour of a watch-face held with 12^h vertical.	....	Id.
e a luminous train ...	....	Towards 3½ hour of a watch-face held with 12^h vertical.	....	Id.
....	....	Towards 7½ hour of a watch-face held with 12^h vertical.	....	Id.
e a luminous train......	....	Towards 4½ hour of a watch-face held with 12^h vertical.	....	Id.
…a train 15° in length..	....	30° left of perpendicular down.	....	W. H. Wood.
....	....	Towards 7½ hour of a watch-face held with 12^h vertical.	....	J. Plummer.
…a luminous train	....	Towards 4½ hour of a watch-face held with 12^h vertical.	....	Id.
…a train	....	....	....	W. H. Wood.
…t yellow train 2½ secs.	....	....	....	Id.
....	5°...........	60° right of perpendicular down.	....	Id.
....	10°	60° right of perpendicular down.	....	Id.
… yellow train 12° long	....	30° left of perpendicular down.	Three very brilliant meteors followed.	Id.
…a bright train for 2 seconds.	....	....	....	Id.
…a bright train for 2 seconds.	....	....	....	Id.
…, bright, ruddy train …2 seconds.	....	....	....	Id.
… train 10° long	....	To left; horizontal......	....	Id.
… train for 1 second...	10°	Parallel to d, α Ursæ Majoris.	....	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 11	h m s 10 9 20 p.m.	Wisbech (Cambridgeshire).	=2nd mag *	....	$1\frac{1}{2}$ second ...	From ꝺ Draconi $\frac{1}{2}$ (γ Lyræ Cygni).
11	10 13 17 p.m.	Ibid	=2nd mag.*	Blue	1 second	From δ Ursæ noris to κ conis.
11	10 16 p.m.	Weston-super-Mare.	> 1st mag.*	Yellow	1 second +...	From Cor Carol
11	10 17 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	1 second	From κ Dracon of the way t Ursæ Minori
11	10 17 20 p.m.	Wisbech (Cambridgeshire).	=1st mag.*	....	$1\frac{1}{2}$ second ...	From θ Cygni Aquilæ.
11	10 22 5 p.m.	Ibid	=2nd mag.*	....	$\frac{1}{2}$ second	From σ to η Ce
11	10 29 p.m.	Weston-super-Mare.	>1st mag.*	Yellow	0·5 second ...	Centre $\frac{1}{2}$ (δ, γ) U Majoris.
11	10 30 10 p.m.	Wisbech (Cambridgeshire).	=3rd mag.*	....	....	Passed a few grees above Pole.
11	10 31 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	0·8 second ...	From $\frac{1}{3}$ (P, M) melopardali t below λ Dr nis.
11	10 33 p.m.	Weston-super-Mare.	=3rd mag.*	Dark yellow colour.	2 seconds......	From the hea Lynx.
11	10 33 30 p.m.	Hawkhurst (Kent).	=$2\frac{1}{2}$ mag.*	Yellow	0·8 second ...	Centre 8° belo Bootis.
11	10 35 p.m.	Ibid	=2nd mag.*	White	1·2 second ...	From Alcor to Ophiuchi, B 4600, Can. Ve ticorum).
11	10 35 p.m.	Wisbech (Cambridgeshire).	=2nd mag.*	....	2 seconds......	From $\frac{1}{2}$ (λ, μ $\frac{1}{2}$ (α, β) culis.
11	10 36 33 p.m.	Ibid	=3rd mag.*	....	$\frac{1}{2}$ second	From r Custodi BAC 2326 melopardali.
11	10 37 p.m.	Weston-super-Mare.	>1st mag.*	....	....	Started at α Cas peiæ.
11	10 39 p.m.	Ibid	=3rd mag.*	....	....	From mouth Ursa Major t below β U Majoris.
11	10 39 23 p.m.	Wisbech (Cambridgeshire).	=2nd mag.*	....	....	From η Persei t Triangulæ.
11	10 40 30 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	1·1 second ...	To α, $\frac{1}{4}$ way fro Bootis.
11	10 43 p.m.	Weston-super-Mare.	=2nd mag.*	Blue	1 second	Commencement Ursæ Majoris.
11	10 43 p.m.	Ibid	=3rd mag.*	Blue........	0·5 second ...	From ψ to ξ U Majoris.
11	10 44 16 p.m.	Wisbech (Cambridgeshire).	=3rd mag.*	....	....	From $\frac{1}{2}$ (η, ϕ) t Persei.
11	10 45 p.m.	Weston-super-Mare.	=1st mag.*	Yellow........	1 second	From γ Ursæ joris.
11	10 46 p.m.	Ibid	=2nd mag.*	Blue........	1 second	From Cor Caroli

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	S. H. Miller.
....	....	....	....	Id.
… a train 10° in length..	....	To left; horizontal......	....	W. H. Wood.
…ntest at first; no train … sparks.	....	....	Clear sky. No shooting-stars after this for 10½ minutes.	A. S. Herschel.
....	....	....	....	S. H. Miller.
....	....	....	....	Id.
…a train 12° long	15°	Directed from R.A. 175°, N. Decl. 65°.	....	W. H. Wood.
....	....	From Cepheus...........	....	S. H. Miller.
… train for 1 second...	....	....	....	A. S. Herschel.
....	5°...........	40° right of perpendicular	Serpentine; slow motion	W. H. Wood.
… train for ½ a second	8°	On a line through δ Ursæ Majoris and Arcturus.	....	A. S. Herschel.
…train for 1 second...	....	....	....	Id.
....	....	....	....	S. H. Miller.
....	....	....	....	Id.
…rain 6° long	....	To right; horizontal ...	....	W. H. Wood.
....	....	....	....	Id.
....	....	....	....	S. H. Miller.
…n or sparks	....	....	....	A. S. Herschel.
....	14°	40° to left of perpendicular down.	Two meteors followed each other closely.	W. H. Wood.
....	....	....	....	Id.
....	....	....	....	S. H. Miller.
....	14°	40° to left of perpendicular down.	....	W. H. Wood.
....	3°, slow ...	30° to right of perpendicular down.	Hid the star Cor Corali in transit.	Id.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863. Aug. 11	h m s 10 52 p.m.	Weston-super-Mare.	=3rd mag.*	Blue............	1 second	From ε Ursæ joris.
11	10 53 30 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·8 second ...	From 3° N. c Lyræ to π I culis.
11	10 59 p.m.	Weston-super-Mare.	=1st mag.*	White	0·5 second ...	Started at γ dromedæ.
11	10 59 31 p.m.	Wisbech (Cambridgeshire).	=2nd mag.*	Blue............	1½ second ...	β Andromedæ t Piscium.
11	11 0 p.m.	Hawkhurst (Kent).	=2nd mag.*	White	0·7 second ...	From ⅓ κ, λ conis to ⅓ Ursæ Majori
11	11 0 p.m.	Weston-super-Mare.	=2nd mag.*	Yellow	2 secs.; very slow.	From β Ursæ joris.
11	11 2 p.m.	Ibid	>1st mag.*	Yellow	1 second	....
11	11 9 p.m.	Ibid	>1st mag.*	Yellow	1 second	From γ Bootis Coronæ.
11	11 15 p.m.	Ibid	=2nd mag.*	Blue	1 second	From γ Ursæ noris to κ conis.
11	11 17 p.m.	Ibid	>1st mag.*	Red	1 second	From mouth o randus to 4° low Polaris.
11	11 24 p.m.	Ibid	>1st mag.*	Yellow	1 second	From 4° abo Ursæ Major β Ursæ Maj
11	11 27 p.m.	Ibid	=1st mag.*	Blue............	1 second	From β Dracoı β Lyræ.
11	11 29 p.m.	Ibid	=1st mag.*	White	1second	From ρ to β Majoris.
11	11 31 p.m.	Ibid	=2nd mag.*	Blue............	1 second	From κ Bootis Ursæ Major
11	11 33 p.m.	Ibid	= to Jupiter	White	1 second	From 13 Camel dali to β Au
11	11 38 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	From the mou Tarandus to Polaris.
12	0 2 a.m.	Ibid	>1st mag.*	Blue, then white.	1 second +...	From Polaris Ursæ Minor
12	0 3 a.m.	Ibid	>Venus, very vivid meteor.	Red, then yellow, then green.	1 second +...	From β A medæ to a R. A. 9°, N. 20°.
12	0 0 15 a.m.	Ramsgate (Kent)	La bright meteor.	....	....	From α Lyræ Herculis.
12	9 24 p.m.	Weston-super-Mare.	= to Sirius	White	1·5 second ...	From γ to ξ I
12	9 28 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	From ξ to σ C peiæ.
12	9 34 p.m.	Ibid	Meteor = to Jupiter	Yellow, then red, then green.	2 seconds......	From R. A. N. Decl. 6 4° below Cameloparc
12	9 38 p.m.	Ibid	=1st mag.*.........	Dark yellow colour.	2·5 seconds ...	Commenced at altitude
12	10 8 p.m.	Hawkhurst (Kent).	=3rd mag.*	Yellow	0·7 second ...	From one qua half the c reckoned fr Persei to φ C

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	45° to left of perpendicular down.	....	W. H. Wood.
…a train for ½ a second	....	....	....	A. S. Herschel.
…a train 4° long	....	To right; horizontal ...	....	W. H. Wood.
....	....	....	....	S. H. Miller.
…a train for 1 second...	....	....	....	A. S. Herschel.
…a train 14° long	....	45° to right of perpendicular down.	....	W. H. Wood.
…a train 6° long.........	6°..........	To left; horizontal	....	Id.
… train	....	....	....	Id.
… train	....	....	....	A. S. Herschel.
…t train	....	....	....	W. H. Wood.
… train	....	....	....	Id.
… train	....	....	....	Id.
… train	....	....	....	Id.
....	....	....	....	Id.
…' white train for 2 …nds.	....	....	....	Id.
… train for 0·5 second	....	....	....	Id.
… train	....	....	....	Id.
…with a flash which …p the landscape. …nt ruddy train 2 …nds.	....	....	See Appendix II. No. (15)	Id.
…nated the footway …andscape.	....	....	See Appendix II. No. (15)	Robert Cramp.
....	....	....	....	W. H. Wood.
....	....	....	....	Id.
…in, 2 seconds	....	....	....	Id.
… 1° long	....	40° to left of perpendicular down.	....	Id.
…n or sparks	....	....	....	A. S. Herschel.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, Altitude a Azimuth
1863. Aug. 12	h m s 10 16 p.m.	Hawkhurst (Kent).	=2½ mag.*	....	....	From σ to ξ conis.
12	10 18 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	1 second +...	From ν Andro
12	10 21 p.m.	Ibid	=1st or 2nd mag.*	Blue	1 second +...	From μ Andi dæ to 56 A medæ.
12	10 24 p.m.	Ibid	=3rd mag.*	Blue	0·5 second ...	Commenced Draconis, p over η Ursa joris.
12	10 27 p.m.	Ibid	=1st mag.*	Blue	0·5 second ...	Passed from α, to β Ursæ joris.
12	10 28 p.m.	Hawkhurst (Kent).	=3rd mag.*	....	0·8 second ...	From θ to 3 of γ Bootis.
12	10 35 p.m.	Weston - super - Mare.	=2nd mag.*	Blue	1 sec. +, slow	From ε Cassi
12	10 42 p.m.	Ibid	=2nd mag.*	Blue	0·5 second ...	From mout Ursa Major or 4° bel Ursæ Majo
12	10 43 30 p.m.	Hawkhurst (Kent).	=3½ mag.*	....	0·7 second ...	From κ Her ¼ of the wa Ophiuchi.
12	10 46 p.m.	Ibid	=3rd mag.*	....	1·2 second ...	Centre at ζ L
12	10 46 p.m.	Clifton (Bristol)	=3rd mag.*	....	1 second	From ⅓ (α Ac θ Pegasi) (β Aquar. Normæ).
12	10 46 30 p.m.	Ibid	=3rd mag.*	....	1 second	From ⅓ (β Ac k Normæ) Capricorni.
12	10 47 p.m.	Hawkhurst (Kent).	=3rd mag.*	White	1 second	From 2° o Bootis to Arcturus.
12	10 48 30 p.m.	Clifton (Bristol)	=1st mag.*	....	1 second	From altitud in S.E. to al 5° through of 7°.
12	10 48 30 p.m.	Hawkhurst (Kent).	=3rd mag.*	Saffron.........	0·4 second ...	Centre ⅓ (N lopardali, A Minoris).
12	10 53 45 p.m.	Ibid	=2½ mag.*	Yellow	1 second	From M Ca pardali to Ursæ Majo Cameloparc
12	10 57 p.m.	Weston - super - Mare.	=3rd mag.*	Blue	0·5 second ...	From α Andro
12	11 10 p.m.	Ibid	= to Sirius	White	1 second +...	From β Peg ¼ (α, ζ) P and 2° furt
12	11 10 30 p.m.	Clifton (Bristol)	>1st mag.*	....	1 second	From ½ λ, η to ¼ (ζ, α gasi.
12	11 17 p.m.	Weston - super - Mare.	=1st mag.*	White	0·5 second ...	From H (30) t β Ursæ M and 5° bey

…earance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
....	....	....	....	A. S. Herschel.
…e a train 12° long	....	70° to right of perpendicular down.	....	W. H. Wood.
…e a train	....	....	....	Id.
…rain or sparks	20°	....	....	Id.
....	8°	....	....	Id.
…a train	....	....	....	A. S. Herschel.
…a train 4° long	....	80° to left of perpendicular down.	Nearly horizontal	W. H. Wood.
…a train	....	....	....	A. S. Herschel.
…ain or sparks	....	....	....	Id.
…t train for 1 second...	15°	Directed from ι Cygni...	....	Id.
....	....	....	....	G. F. Burder.
....	....	....	....	Id.
…ft train	8°	Directed from η Ursæ...	....	A. S. Herschel.
....	7°	....	....	G. F. Burder.
....	5°	Directed from ϵ Ursæ Minoris.	....	A. S. Herschel.
…t train for 1 second...	....	....	....	Id.
....	20°	Fell vertically	....	W. H. Wood.
…t train	....	Almost vertical	....	Id.
....	....	Course nearly vertical...	....	G. F. Burder.
… track upon the …he course.	....	....	....	W. H. Wood.

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Position, or Altitude and Azimuth.
1863.	h m s					
Aug. 12	11 26 p.m.	Weston-super-Mare.	=1st mag.*	White	1 second	From β Bootis to · Coronæ.
12	11 30 30 p.m.	Clifton (Bristol)	=2nd mag.*	....	1 second	Centre $\frac{1}{2}$ ϵ Pegasi β Equulei.
12	11 32 30 p.m.	Ibid	=3rd mag.*	....	1 second	From $\frac{1}{2}$ α, ζ Aquil to $\frac{1}{2}$ (η, θ) Serpentis.

APPENDIX.

I. Biographical Notice of E. C. Herrick, late Treasurer of Yale College, Newhaven, Connecticut, U.S.

Edward Charles Herrick, the late promoter of meteoric astronomy in America, and the subject of this notice, was born at Southampton, Long Island, New York, on the 24th of February 1811. As clerk in an extensive book-store, he cultivated an early taste for accurate knowledge by successful studies in entomology. After a memorable storm of falling stars in November 1833 had fixed the attention of scientific men, Herrick directed his talents to the field of meteoric astronomy, and remained until the middle of the past year the most vigilant observer and the most careful recorder of wandering stars in the New World. We owe to Herrick and to Quetelet the knowledge of the periodical meteors of the 10th of August. The discovery of this important date was made independently by Herrick in 1837, and by M. Quetelet in 1836*. Both observers maintained after that time a yearly watch for the display, and published their observations in the Journals of their respective countries. The annual frequency of meteors on the 20th of April, in the middle of October, and on the 6th to the 8th of December, their greater frequency in the morning hours of the night, and their greater abundance in America than in Europe, are facts of which we owe the earliest knowledge to the observations of Herrick. M. Quetelet thus wrote to Herrick in 1861. "The additions which you have made to science will always be among the most important and among the most useful for the conclusions which have hitherto been drawn from them." Herrick died on the 11th of June 1862, in the 52nd year of his age, being Librarian of Yale College in 1843, Librarian and Treasurer in 1852, and Treasurer in 1858. He is succeeded in the Committee of the Connecticut Academy for the observation of luminous meteors by Professor H. A. Newton, of Yale College, whose recent contributions to the American Journal of Science greatly advance the present state of meteoric science.

II. Meteors doubly observed.

(1.) 1859, October 25th, 7^h 15^m P.M.

The meteor seen at Holyhead, and twelve miles W. of Athlone (in Ireland),

* American Journal of Science, 1st Series, vol. xxxiii. p. 401.

Appearance; Train, if any, and its Duration.	Length of Path.	Direction; noting also whether Horizontal, Perpendicular, or Inclined.	Remarks.	Observer.
Left a train	....	....	....	W. H. Wood.
No train or sparks	15°	Directed from η Pegasi	....	G. F. Burder.
No train or sparks	....	....	....	Id.

appears to have been directed nearly upon the latter place, and to have flown 140 miles in three to five seconds, from seventy miles above Southport in Lancashire to twenty miles above Balbriggan on the Irish coast. At fifty miles from Holyhead this meteor produced an illumination like daylight, and which cannot have fallen far short of the full moon. An equivalent globe of gas-flame should be 40 feet in diameter to produce a similar effect.

(2.) 1860, November 1st, 8^h 30^m P.M.

A falling star as bright as Mars, and throwing off discharges of fragments, observed by Mr. Lowe at Beeston and by Mr. Penrose at Swanage, although roughly observed at the latter place, can be seen to have flown upwards of sixty miles in three seconds, from eighty miles above Wolverton (in Bucks) to thirty miles above Warwick. At 945 yards it would have shone with the brightness of full moon, and the diameter of an equivalent globe of gas-flame would be 24 inches to produce a similar effect. The colour of this falling star was red, and no train was left upon the track.

(3.) 1862, September 19th, 5^h 50^m P.M.

This meteor appeared as a brilliant fireball, even amidst the rays of the setting sun. Exact measurements of the flight are wanting for the estimation of its real path; but it appears to have pursued a track perfectly similar to that of the meteor which followed it upon the same evening.

(4.) 1862, September 19th, 10^h 15^m P.M.

This extraordinary meteor exploded in the zenith of London. Three independent calculations, by Mr. Wood, Mr. Burder, and Mr. Herschel, agreed in placing the height of this outburst of light between fifty-five and sixty miles above the city or very little towards the South of London; and from the extreme brilliancy of the spectacle, it is probable that at places 150 miles from the meteor, the splendour of full moon was experienced from its light. On this estimation a globe replete with gas flame 83 feet in diameter would adequately represent the illuminating power of the flash. The remainder of the flight is variously assigned, from 126 miles over Boulogne, or from eighty-three miles over Canterbury, to thirty miles over Oxford, thirty miles over Chesham (in Bucks), or thirty-three miles over Woodstock in Oxfordshire. No report was heard to follow the explosion of the meteor.

(5.) 1862, September 22nd, 10^h 22^m P.M.

This falling star resembled in character that of November 1st, 1860 (No. 2). The point of disappearance is situated twenty miles above Dungeness Point, where the meteor arrived from an origin exhibiting little apparent parallax at London and Etchingham, but having its direction in the constellation of the Dolphin. If the commencement of the visible path is placed 150 miles above the Cape of la Hogue, an interval of 170 miles to the point of extinction was traversed by this meteor in $4\frac{1}{2}$ seconds of time. The meteor resembled Mars. A globe of ignited gas two feet in diameter would sufficiently represent the intensity of its light.

(6.) 1862, September 25th, 6^h 15^m P.M.

Exact accounts of the two meteors which appeared in the South of England at sunset of this evening are rare. The first was distinguished by a remarkable contrast of red and green colour in the head and *vaporous envelope* of the meteor. A low flight with moderate velocity over the county of Hampshire, is rendered probable by the observations at Weston-super-Mare, Ventnor, Lamberhurst, and Ticehurst, performing sixty or seventy miles in six or seven seconds of time from forty-five miles above Petworth in Sussex, to fifteen miles above Salisbury town. The meteor was splendid even in daylight, but no report was audible.

(7.) 1862, September 25th, 6^h 30^m P.M.

The second meteor was vertical at Weston-super-Mare. It was seen at a considerable altitude in the S.W. at Hay and Great Malvern, and nearly in the zenith at Kimmeridge in Dorsetshire, at the time of its first appearance, descending thence towards the south of west from all the stations where it was observed. A nearly horizontal course from sixty miles above Swindon in Wiltshire to forty miles above Padstow in Cornwall, corresponds most closely with the observations of the flight. This meteor was globular, white or blue, and attained a size before disappearance compared at Corwen in North Wales with that of the moon. No report followed its disappearance.

(8.) 1862, November 16th, 10^h 45^m P.M.

If this meteor did not move over the open sea, it may be surmised to have passed above Start Point (at a height of forty miles), and downwards towards the sea in the neighbourhood of St. Ives, in Cornwall. This result is uncertain, from the absence of precision in the observations. The meteor appears indeed to have been of the class of larger falling-stars*, and not a distant fireball.

(9.) 1862, November 26th, 6^h 40^m P.M.

Vertical over Selkirk. At Leeds the meteor traversed the last two stars in the tail of Ursa; its middle point had an altitude of 19° directly over Selkirk. The height above this town was therefore forty-two miles, and in its onward course the meteor was directed to an earth point upon the Kirkcudbright coast. The meteor terminated at an elevation of twenty miles, with great brilliancy, and with a loud report audible at Selkirk.

(10.) 1862, November 27th, 5^h 47^m P.M.†

The path of this brilliant meteor was sensibly horizontal. From thirty miles above the mouth of the Scheldt (lat. N. 52° 6′, long. E. 3° 7′), to twenty-eight miles above the mouth of the Seine (lat. N. 49° 49′, long. W. 0° 23′), the meteor travelled 220 miles with varying brilliancy in 5 seconds. At

* See Nos. (2) and (5).

† See this Appendix, No. III.

Caen in Normandy, forty-five miles from the explosion, a loud report was heard after the disappearance of the meteor. The diffused light at Hawkhurst resembled perfectly the light of the half moon, then shining in the same direction. At thirty miles the meteor would have rivalled in splendour the full moon, and a globe 29 feet in diameter, replete with ordinary gas flame, would suffice for an equal luminous effect.

(11.) 1863, January 27th, $5^h\ 30^m$ P.M.

This meteor appeared in strong daylight. Six miles S.E. of Stirling it appeared to descend vertically upon Bannockburn; and at Auchterarder, in continuation of the same line, it passed overhead, still going north-eastward to the horizon.

(12.) 1863, February 7th, $6^h\ 30^m$ P.M.

An exceedingly large meteor appeared before the departure of twilight. At Loch Fine in Argyllshire, at Lauder in Berwick, and at Elie and Leven in Fifeshire, it presented the same appearance of a body moving horizontally in S.W. (from N.W. to S.E.);—and the variation of altitude in the west and east of Scotland was no more than 25° to 12½°. The meteor appears to have skirted the westernmost points of the Scottish Isles, from Barra Head to the Mull of Galway, at thirty-six miles above the sea, and was doubtless observed at Belfast as a striking object. At eighty miles from Greenock, a flash like that of lightning was produced in closed apartments. If the meteor rivalled the light of full moon at this distance, an equal light would be produced by a globe of ordinary gas flame 56 feet in diameter.

(13.) 1863, March 4th, $6^h\ 36^m$ P.M. G.M.T.

Dr. Ed. Heis, Director of the Royal Observatory at Münster, has published a pamphlet containing the particulars of 100 different accounts of this meteor, of which the following is a short abstract. The meteor at first resembled a bright shooting-star, advancing with leisurely speed and expanding until it appeared, to some observers, to attain the apparent size of the full moon, which was then above the horizon. The landscape was everywhere illuminated as if with the strongest artificial light, and to the majority of the observers the meteor appeared to fall within a few yards of their position at the time. Drs. Baumhauer and Krecke communicated particulars of the meteor to Prof. Heis from stations in Holland and Belgium, and M. Quetelet* from Brussels, Mr. Greg from Manchester and different parts of England. From astronomical friends, and from other sources in Rheinland, Hanover, Holland, England, &c., M. Heis received upwards of 100 different accounts. The meteor was visible over an area of 100,000 square miles, including in a six-sided figure the towns of Manchester, Brighton, Treves, Erbach (Odenwald), Hanover, and the northern coast of the kingdom of Hanover. The extent of this area is, from Manchester to Erbach, 553 miles; from Brighton to Bremen, 401 miles. The duration of the flight was between 4 and 5 seconds, or, according to five trustworthy accounts, 3½, 5, 4, 4, and 5½ seconds of time.

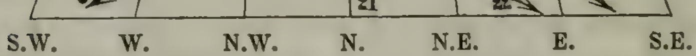
The time of disappearance		7^h	6^m	P.M.,	Münster mean time,
,,	,,	6	45	,,	Paris ,,
,,	,,	6	35½	,,	Greenwich ,,

The figure of the meteor was elongated, appearing circular in the direction

* Bulletins of the Belgian Academy of Sciences, 2nd Series, vol. xv. No. 3.

of its motion, but in a transverse direction conical or pyriform, with a length from four to ten times its greatest width. Two trustworthy accounts at Brussels and Utrecht give half the diameter of the full moon as the approximate apparent width of the head, from which M. Heis infers a diameter of 460 yards for the nucleus or focus of the light. In the early part of its flight the meteor nevertheless resembled an ordinary shooting-star, and only gradually attained its greatest splendour. An imposing light was thrown upon the landscape in the greater part of the area over which the meteor was visible. In comparison with this, the full moonlight appeared to pale into insignificance, and in some towns of Belgium the light was even compared with that of day. The colour of the meteor, in the zenith of the observers, changed from white to deep red, which was also the colour of the pointed tail. At last the meteor disappeared suddenly, without breaking into fragments. The tail, however, contained parcels of vari-coloured light, which appeared to be detached during the flight. At Eerzel the meteor appeared as a small stationary moon or ball of light at the centre of a conflagration which exhibited kaleidoscopic colours. The ball itself was red. It presented the same appearance through the windows of a side aisle in the church of Looz, and its passage across the west window of the Cathedral in Münster afforded means for accurately determining the apparent course at that place. Many of the local accounts collected by M. Heis in a journey of three days, undertaken in May near the line of termination of the meteor, are instances of lively terror occasioned by a meteor of the largest class. A report was heard in North Brabant like the explosion of a distant powder-mill, at which the earth trembled, and houses and windows were shaken. The interval elapsed was a minute at Herzogenbosch, and yet smaller near Eerzel and Eindhoven, where the meteor was vertical at disappearance. The reports also resembled those of cannons in irregular succession, followed for 20 or 40 seconds by rattling noises, which gradually expired. These sounds were heard to a distance of eighty miles north-east from the explosion.

The apparent paths, observed in different quarters of the heavens, show the meteor to have advanced from 5° W. of N., altitude 22°. In the case of

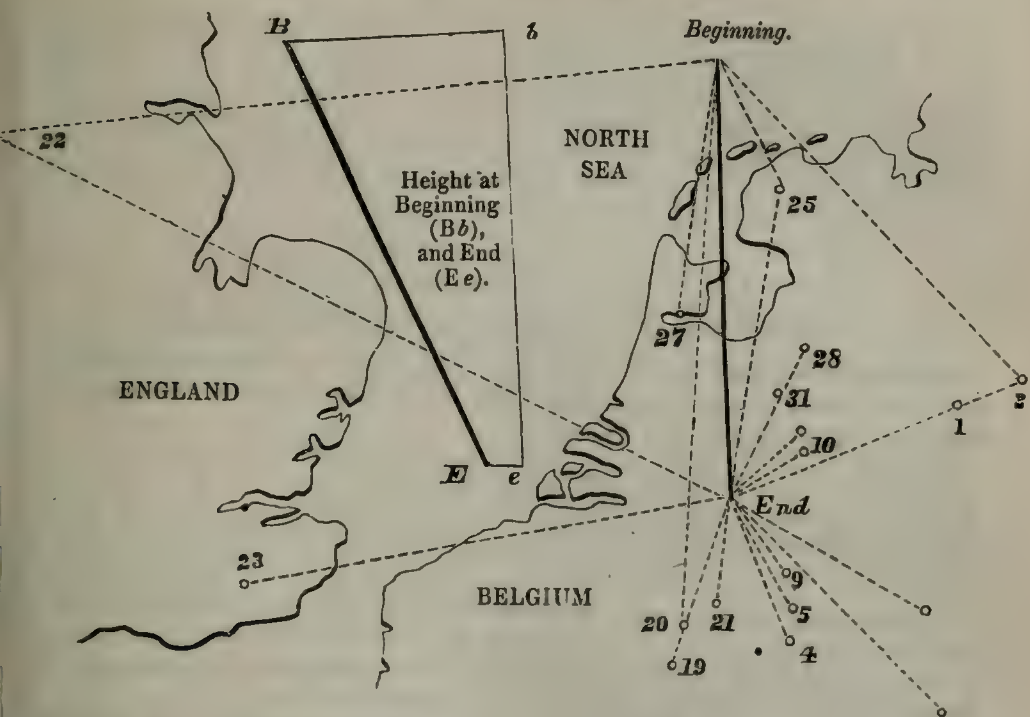


3. Hanover.
14. Brussels.
17. Ypers.
27. Leyden.
32. Maestricht.
37. Eerzel.
40. Helmond.

meteorites and oblique meteors the points of the horizon towards which they appear to move depend upon the geographical positions of the observers, and cannot be employed alone.

At Münster the apparent course was referred to the stars, but three only out of forty exact observations were recorded in a similar manner. The

accompanying chart represents the comparison of these accounts. The meteor accomplished a visible course of 187 miles in 4 or 5 seconds of time, with a velocity of $41\frac{1}{2}$ miles per second, from eighty-eight miles above the North Sea



1. Münster.
2. Borgholzen.
4. Eupen.
5. Richterich.
9. Walbeck.
10. Goch.
19. Namur.
20. Jodoigne.
21. Looz.
22. Manchester.
23. Hawkhurst.
25. Leuwarden.
27. Zaandam.
28. Deventer.
31. Arnheim.

in N. lat. 53° 50′, E. long. 5°, to 17 miles above the southern part of North Brabant in N. lat. 51° 28′, E. long. 5° 18′, with a (geocentric) trajectory directed from R. A. 270°·5, N. Decl. 61°. The heliocentric trajectory is from R. A. 337° 47′, N. Decl. 81° 39′.

The orbit about the sun, according to Professor Heis, is direct hyperbolic, like that formerly calculated by M. Petit, Director of the Observatory of Toulouse, of a meteor seen on the 29th October 1857.

The elaborate explorations of Dr. Heis in the neighbourhood S. of Herzogenbosch in North Brabant, describe the district where fragments of the meteor may in future be found, if the destructible nature of meteoric stones leave still any hope of their recovery.

(14.) 1863, March 23rd, 8^h 30^m P.M.

This meteor was the subject of numerous observations. It originated nearly fifty-five miles above the sea, fifteen miles southward from Chale (in the Isle of Wight), and shot sixty miles in three seconds, disappearing without audible report fifteen miles above the sea, seventy miles S. of Purbeck

Isle in Dorsetshire. A globe of gas flame 16 feet in diameter would represent the light of this meteor according to the best accounts of its appearance.

(15.) 1863, August 12th, 0^h 3^m A.M.

This meteor illuminated the scene at Weston-super-Mare in Somersetshire and at Ramsgate in Kent with a flash of diffused light. The path concluded from the observations is from 122 miles above Cobham (in N. lat. 51° 17′, W. long. 0° 25′) to eighty-six miles above Havant (in N. lat. 50° 51′, W. long. 0° 54′). The visible flight of fifty-two miles was performed in rather more than one second of time, from the direction of 32° east of north, altitude 45°, terminating in a flash of brilliant light.

III. Path of Meteor, 1862, November 27th, 5^h 47^m P.M.

Calculated from ten accounts of the foregoing Catalogue.

Of ten observations, four lines of sight of the point of disappearance intersect each other, twenty-eight miles high above the mouth of the Seine in long. W. 0° 23′, N. lat. 49° 49′, viz.:

Grantham	Meteor vanished	4° E. from S.	Altitude 7°.
Saltford	Meteor vanished	38° E. from S.	Altitude 10°.
Weston-super-Mare	Meteor vanished	45° E. from S.	Altitude 10°.
Tunbridge	Meteor vanished	15° W. from S.	Altitude 18°.

A provisional path to this point of disappearance, from fifty-five miles above the mouths of the Scheldt (long. E. 3° 40′, N. lat. 51° 21′), is approached, in the following manner, by four other observations of the point of disappearance or explosion. The line of sight at—

Sunderland	(5° W. from S.,	alt. 3°) is	1° *above*,	11° *onwards*	from disappear^ce^.
Clapham	(11° ,,	alt. 18°) is	6° ,,	5° ,,	,,
Hawkhurst	(14° ,,	alt. 15°) is	5° *below*,	0° ,,	,,
Deal	(26° ,,	alt. 20°) is	3° ,,	13° *backwards*	,,
	Difference	....	1° *below*,	3° *onwards*	,,

The place of disappearance is therefore determined by four intersecting observations, as well as by four other observations whose errors very nearly balance each other about the same point.

The ten observations of the earlier portions of the meteoric track pass, with respect to the provisional path, according to the following Table of errors.

The observation of first appearance at—

	Distance. Miles.			Before extinction. Miles.
Sunderland	320	(40° E. from S., alt. 9°)	is 10 miles below the track	210
Grantham	200	(35° ,, ,, 11°)	is 3 ,, above ,,	104
Saltford	160	(68° ,, ,, 10°)	is 3 ,, below ,,	88
Weston-super-Mare	300	(Due E., alt. 10°)	is 12 ,, ,, ,,	190
Clapham	110	(28° E. from S., alt. 17°)	is 3 ,, ,, ,,	65
Tunbridge	90	(44° ,, ,, 33°)	is 14 ,, above ,,	85
Hawkhurst	85	(8° ,, ,, 30°)	is 2 ,, ,, ,,	50
Deal	70	(44° ,, ,, 33°)	is 12 ,, ,, ,,	125
Cambridge	160	(5° ,, ,, 16°)	is 12 ,, ,, ,,	22
Broxbourne	120	(23° ,, ,, 19°)	is 1 ,, ,, ,,	83

Seen from the point of explosion, these ten observations of first appearance

surround the provisional path very closely, but are more crowded together north from, and below the provisional track. The ten lines of sight, drawn in perspective from the point of disappearance, and strengthened in proportion to the proximity and early view of the meteor (contained in the first and last columns of the Table), indicate a point 15° northward and 6° below the centre of the projection as the most probable direction from which the meteor approached its bursting point. The corrected path is horizontal directed from azimuth 225° (W. from S.), and commenced thirty miles above the mouth of the Scheldt in long. E. 3° 7′, lat. N. 52° 6′; the termination, as before, being twenty-eight miles above the mouth of the Seine in long. W. 0° 23′, lat. N. 49° 49′, thirty miles N. of Caen, and seventy miles S. of Worthing in Sussex. At Caen, in Normandy, a loud detonation followed the disappearance of the meteor. The length of the path is 220 miles, performed in four or five seconds of time.

It is probable from one account of the first appearance, and from the irregular form which this meteor afterwards assumed, that a group of many fragments composed the meteoric mass after its collision with the atmosphere.

IV. Meteoric Shower of April 1863, and Conclusions of Professor H. A. Newton.

A considerable fall of meteors was observed in England on the morning of the 21st April 1863, from Newe (Aberdeenshire) in the north, to Weston-super-Mare (Somersetshire), and Hawkhurst (Kent), in the south of England; followed, on the evening of the 22nd, by a total absence of meteors during several successive hours (see Catalogue). At 3^h A.M., on the 21st April, the number was 40 per hour for a single observer. The definite nature of this phenomenon led to a comparison with the great shower recorded by Herrick to have happened on the morning of the 20th April 1803. The observations rendered it certain that the date of the cosmical phenomenon had advanced twenty-four hours in the course of sixty years, but the cause was not detected*.

Professor H. A. Newton, in the American Journal of Science and Art (vol. xxxvi. p. 145), has shown that the precession of the equinoxes produces a delay of *one day in seventy years*, upon the return of all the known periodical meteoric showers, of April, August, November, and December. In the following lists, the dates of the star-showers of early history have been corrected by this amount from the moveable equinoxes of the early dates to the fixed equinox for the year 1850.

1st. The April shower.

B.C.	687.	March 16	corresponds	to A.D.	1850,	April	19·9.	Biot.
	15.	„ 25	„	„	„	„	19·6.	Biot.
A.D.	582.	„ 31	„	„	„	„	18·1.	Chasles.
	1093.	April 9·6	„	„	„	„	20·7.	Chasles.
	1094.	„ 10	„	„	„	„	20·8.	Chasles.
	1095.	„ 9·6	„	„	„	„	20·2.	Herrick.
	1096.	„ 10	„	„	„	„	21·3.	Herrick.
	1122.	„ 10·6	„	„	„	„	20·2.	Herrick.
	1123.	„ 11	„	„	„	„	20·4.	Chasles.
	1803.	„ 19·6	„	„	„	„	19·9.	Herrick.

Mean...1850, April 20·1

* Bulletins of the Belgian Academy of Sciences, 2nd Series, vol. xvi. p. 7.

2nd. The August shower.

A.D. 830.	July	26	corresponds to	A.D. 1850,	August		9·2.	Biot.
833.	„	27	„	„	„	„	10·4.	Biot.
835.	„	26	„	„	„	„	8·9.	Biot.
841.	„	25	„	„	„	„	8·4.	Biot.
924.	„	26–28	„	„	„	„	8·1–10·1.	Biot.
925.	„	27–28	„	„	„	„	8·8– 9·8.	Biot.
926.	„	27	„	„	„	„	8·6.	Biot.
933.	„	25–30	„	„	„	„	5·8–10·8.	Biot.
1243.	August	2	„	„	„	„	10·6.	Herrick.
1451.	„	5	„	„	„	„	10·0.	Biot.

Mean...1850, August 9·0

3rd. The November shower.

A.D. 585.	October	25	corresponds to	A.D. 1850,	November		12·3.	Chasles.
902.	„	29·30	„	„	„	„	11·0–12.0.	Herrick.
1582.	November	7	„	„	„	„	10·7.	Wartmann.
1698.	„	8·6	„	„	„	„	11·6.	Wartmann.
1799.	„	11·6	„	„	„	„	12·9.	Humboldt.
1833.	„	12·7	„	„	„	„	13·3.	Olmsted.

Mean...1850, November 12·0

4th. The December periods.

That of December 6th, 7th is not marked by any early appearances. The following early dates belong to the second shower:—

A.D. 901.	November	30	corresponds to	A.D. 1850,	December		13·3.	Herrick.
930.	„	29	„	„	„	„	11·6.	Biot.
1571.	December	8	„	„	„	„	11·5.	Wartmann.

Mean...1850, December 12·1

From the consistency of these results, Professor Newton draws a powerful argument in favour of the cosmical origin of the periodic shooting-stars. The following dates are selected from his list as favourable for the appearance of meteoric showers, viz., January 15th to 19th, February 19th, March 1st to 4th, April 28th to 30th, October 16th to 18th, and October 31st to November 6th. The last period includes the occurrences of several of the most remarkable showers on record*.

V. Meteoric Shower of August 1863.

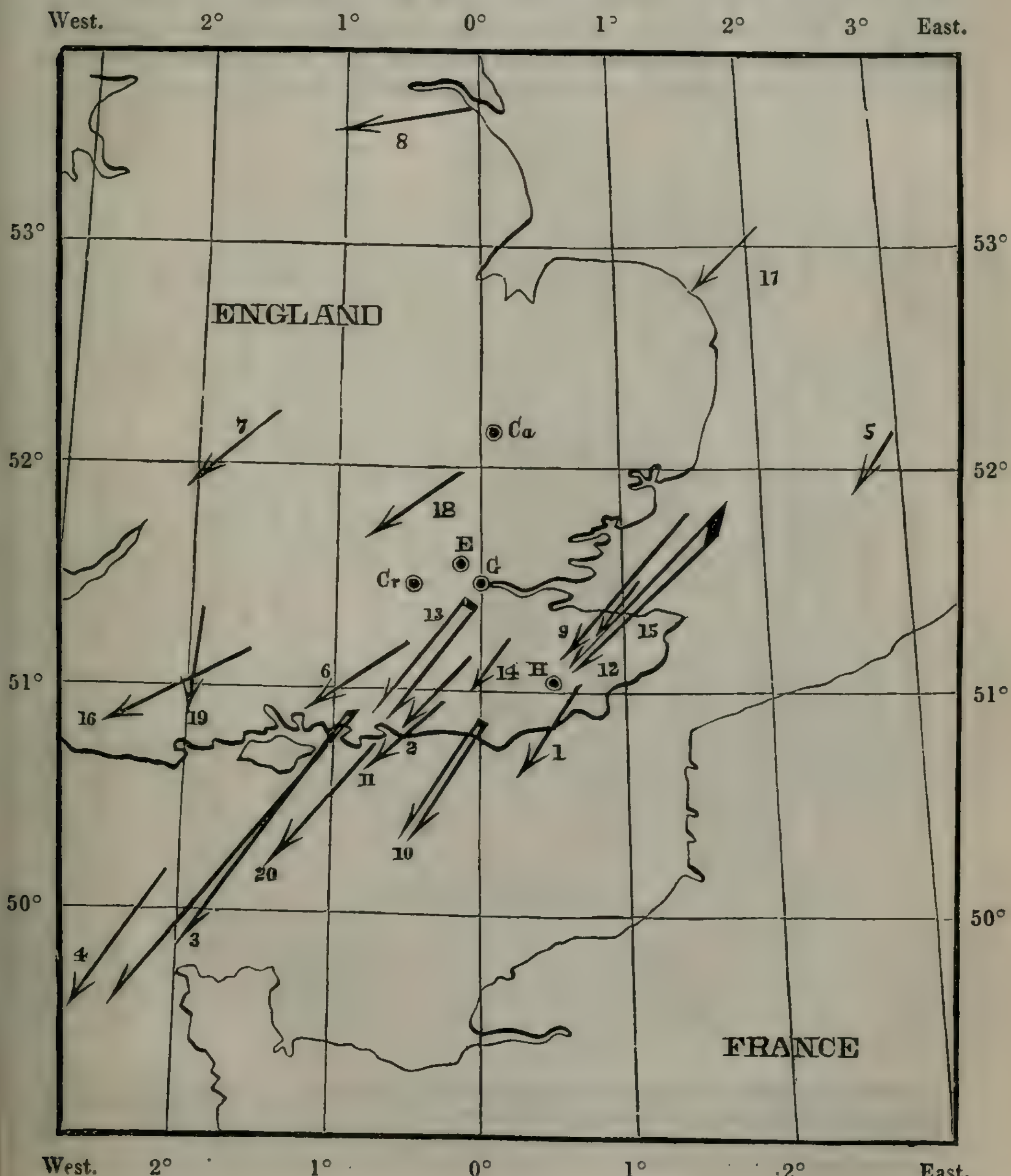
On the 9th and 10th of August 1863, observations were made at the Greenwich and Cambridge Observatories, at Cranford and Euston Road Observatories, and at Hawkhurst, for determining the heights and velocities of the annual shooting-stars of this period. The following meteors were simultaneously observed on those evenings at one or more of the observatories, and at Hawkhurst. The full particulars of the observations are given in the foregoing Catalogue.

In Table I., the numbers in the first column refer to the meteors on the chart in the order of their appearance, and the stations are represented in the same table for shortness by their initial letters, viz.: Ca. *Cambridge*, Cr. *Cranford*, E. *Euston Road*, G. *Greenwich*, H. *Hawkhurst*.

* The same mode of correction applied to Mr. Greg's Catalogue of Fireballs, contained in the British Association Report for 1860, shows that the 28th January, 10th February, 10th April, 18th, 20th, and 29th July, 4th and 12th August, 13th, 18th, and 24th October, 13th to 15th, and 21st November, 11th and 21st December, are dates preferred among the larger kind of meteors.

The mean height of first appearance of the meteors derived from Table II. is 81·6; that of disappearance 57·7 miles above the surface of the earth. The mean direction of their flight is from azimuth 222° (W. from S.), altitude 28°; and at the mean hour $10^h\ 16^m\ 37^s$ P.M. of the appearances, this point was situated in R. A. 43°·1, N. Decl. 50°·8, not far from the bright star (γ) of the constellation Perseus.

The mean of the velocities in Table III. is thirty-nine miles per second for seventeen observations; but if we exclude the velocities of sixty-one miles and seventy miles per second of meteor No. (12), and that of seventy-five miles per second of meteor No. (9), as evidently in error, the mean geocentric velocity of the fourteen remaining observations is 34·3 miles per second, which agrees



closely with values elsewhere obtained, and hitherto accepted*. The remaining columns of this Table contain the illuminating power of each meteor during the period of its visible flight. The quantity is expressed by the volume of ordinary coal-gas which would be required to supply an equal illumination for an equal space of time, by combustion with ordinary expedients in atmospheric air. The heat of this combustion, converted into foot pounds, furnishes the numbers for the last column in the Table. They represent the mass of meteoric matter, moving with a geocentric velocity of thirty miles per second, which such an amount of free caloric, if applied directly, would be able to arrest. These may be taken to represent roughly the weights of the meteoric particles before dissolution by the heat and pressure of their contact with the air. The use of the oxyhydrogen lime-flame, or the flame of the electric arc, as the medium of comparison in place of ordinary gas-flame, would probably confirm the suspicion that even smaller quantities of meteoric matter than these create the generality of falling-stars.

Table I.

No.	Date, 1863. Aug.	G.M.T.	Station.	Began.		Ended.		Station.	Began.		Ended.	
				Azimuth. W.from S.	Altitude.	Azimuth. W.from S.	Altitude.		Azimuth. W.from S.	Altitude.	Azimuth. W.from S.	Altitude.
		h m s		°	°	°	°		°	°	°	°
1	9	9 53 0	H.	266·0	83·0	30·2	62·5	E.	219·0	61·0	252·3	43·2
2	9	10 18 0	H.	115·5	71·7	70·7	41·7	E.	352·8	72·0	337·8	39·2
3	10	9 21 35	H.	79·2	49·2	51·0	20·8	E.	37·0	58·0	34·7	22·2
4	10	9 36 30	H.	60·0	42·0	50·2	22·8	E.	41·0	41·0	39·7	22·7
5	10	9 46 10	H.	230·5	20·7	241·2	12·0	Ca.	265·3	23·0	281·5	11·5
6	10	9 53 28	H.	99·5	61·3	83·7	51·0	Ca.	21·8	47·7	29·5	39·5
7	10	9 56 45	H.	136·3	31·8	121·3	22·7	Ca.	91·8	49·0	79·2	29·8
8	10	10 4 20	H.	172·7	16·8	161·2	13·0	Ca.	176·6	29·1	155·6	22·7
9	10	10 6 0	H.	221·5	61·0	212·5	82·5	E.	256·0	62·0	213·7	59·0
10	10	10 6 35	H.	60·0	68·8	39·8	40·3	Cr.	337·5	53·3	1·0	33·8
11	10	10 9 0	H.	78·0	73·2	65·2	47·2	E.	8·0	69·3	22·7	45·2
12	10	10 11 30	H.	221·5	55·8	207·5	83·3	G.	249·0	57·5	307·8	57·0
13	10	10 18 50	H.	140·2	65·0	77·0	50·2	Cr.	275·0	78·0	14·0	55·5
14	10	10 33 29	H.	133·0	72·7	92·0	67·0	Ca.	357·8	43·3	3·8	33·5
15	10	10 40 20	H.	218·7	58·7	219·4	69·3	Ca.	316·7	47·8	333·7	40·0
16	10	10 41 30	H.	93·8	43·2	84·0	33·3	Ca.	44·0	39·0	49·0	30·0
17	10	10 46 46	H.	204·7	28·7	199·0	27·2	Ca.	233·5	39·8	233·5	42·3
18	10	10 52 26	H.	155·5	47·5	130·0	45·8	Ca.	32·8	74·3	44·2	54·3
19	10	11 7 1	H.	100·2	31·0	85·7	18·5	Ca.	53·2	30·5	44·3	15·7
20	10	11 9 0	H.	85·5	64·7	56·7	32·8	G.	27·3	66·5	34·7	33·3
						Additional Observations.						
3	...	...	...	...	...	...	...	Cr.	128·0	24·5	58·0	33·0
10	...	...	...	...	...	...	...	Ca.	2·3	33·5	10·0	22·2
12	...	...	..	...	...	...	...	Ca.	254·0	51·0	298·8	45·8
13	...	...	...	...	...	...	...	Ca.	4·8	53·0	18·3	31·2

* The mean height at first appearance of 178 falling stars observed since the time of Brandes and Benzenberg (1798) is 70·05 miles. The mean height of disappearance of 210 shooting-stars is 54·22 miles. The mean length of path of 66 is 46·18 miles; and the mean velocity of 37 is 34·35 miles per second, relatively to the earth.

TABLE II.

No.	Beginning.				End.			
	Lat. N.	Long.	Height in miles.	Distance from Hawkhurst.	Lat. N.	Long.	Height in miles.	Distance from Hawkhurst.
	° ′	° ′		miles.	° ′	° ′		miles.
1	51 2	0 39 E.	86	86	50 42	0 18 E.	58	66
2	51 10	0 2 W.	75	79	50 48	0 36 W.	44	67
3	50 53	0 55 W.	72	95	49 54	1 56 W.	53	143
4	50 6	2 5 W.	114	173	49 33	2 39 W.	73	188
5	52 14	3 8 E.	55	154	51 55	2 51 E.	25	120
6	51 9	0 33 W.	87	99	50 56	1 3 W.	84	108
7	52 14	1 20 W.	71	135	51 57	1 57 W.	52	134
8	53 34	0 2 W.	55	188	53 32	0 52 W.	42	188
9	51 48	1 30 E.	131	149	51 8	0 35 E.	66	66
10	50 51	0 0	63	68	50 20	0 27 W.	53	83
11	50 56	0 15 W.	109	114	50 42	0 41 W.	62	83
12	51 51	1 45 E.	122	146	51 6	0 35 E.	55	55
13	51 26	0 2 W.	79	87	50 57	0 37 W.	58	76
14	51 13	0 9 E.	64	66	51 3	0 2 W.	53	58
15	51 30	1 7 E.	72	84	51 16	0 48 E.	60	64
16	51 7	1 35 W.	85	124	50 50	2 24 W.	83	151
17	53 4	2 8 E.	86	179	52 49	1 33 E.	68	149
18	51 57	0 9 W.	76	103	51 41	0 43 W.	71	99
19	51 18	1 52 W.	62	120	50 56	1 55 W.	35	111
20	50 59	0 24 W.	86	95	50 14	1 18 W.	65	122
From the additional Observations.								
3	50 54	0 51 W.	70	91	49 34	2 21 W.	62	172
10	50 51	0 1 E.	62	67	50 20	0 25 W.	53	83
12	51 42	1 37 E.	102	123	51 6	0 36 E.	50	51
13	51 24	0 1 E.	74	81	50 52	0 36 W.	59	77

The light of full moon has been equated by Sir John Herschel (Cape Observations, p. 353 *et seq.*) to 6852 × Sirius, 54,816 × α Lyræ, 78,770 × Altair, 160,000 × α Persei, and to 318,900 × Cor Caroli. It is further compared in this place to a flame consuming 4½ cubic feet per hour of ordinary coal-gas at a distance of 15 yards, or to a flame consuming 17·2 cubic feet of coal-gas per second, at the distance of a mile.

According to Despretz (quoted by Brande, 'Manual of Chemistry,' 1848, p. 275), a single cubic foot of ordinary coal-gas containing 147 grains of pure carbon and 63 grains of pure hydrogen, would raise the temperature of 677 lbs. of distilled water 1° Fahrenheit by its combustion in atmospheric air. The mechanical equivalent of this quantity of heat is nearly 522,000 foot-pounds, of which 55,675 represent the dynamical energy of a grain weight of matter animated by a velocity of thirty miles per second. A single cubic foot of coal-gas would, on this assumption, suffice to arrest the motion of 9·378 grains weight of matter moving with a geocentric velocity of thirty miles per second. The weights of the last column are therefore found by multiplying the numbers of the preceding column by the constant factor 9·378 grains.

TABLE III.

No.	Length of Path, in miles.	Duration (Hawkhurst).	Velocity, miles per second.	Direction of flight. From Azimuth, W. from S.	Alti-tude.	Apparent brightness at Hawkhurst.	Light of meteor at 1 mile compared to full moon.	Consumption of coal-gas for luminous effect equal to that of meteor.	Weight of meteoric matter arrested at 30 miles per second.
		sec.		°	°			cubic feet.	lbs. oz. grs.
1	41	1·0	41	218	40	Altair	0·07	12·6	0 0 109
2	48	1·4	34	222	40	Altair	0·07	16·3	0 0 141
3	84	3·0	28	213	13	Jupiter	8·27	4264·0	5 4 162
4	71	1·7	38	249	42	Jupiter	19·02	5560·0	8 14 0
5	46	...	...	193	40	Venus	13·70	2356·0	2 14 267
6	26	1·0	26	234	6	α Persei	0·07	11·5	0 0 100
7	38	1·0	38	235	32	α Persei	1·13	19·4	0 0 168
8	39	1·3	30	262	18	Sirius	5·16	1153·0	1 6 359
9	90	1·2	75	219	47	Sirius	1·69	348·1	0 6 389
10	46	...	...	209	13	Sirius	0·83	143·0	0 2 363
11	54	1·6	33	228	62	α Lyræ	0·18	48·7	0 0 421
12	100	1·4	71	220	42	Sirius	1·47	354·7	0 7 9
13	48	1·5	32	215	26	Venus	4·85	1251·0	1 8 328
14	18	0·8	23	212	34	α Persei	0·02	3·5	0 0 29
15	25	0·5	50	216	29	α Persei	0·03	2·9	0 0 25
16	41	...	...	238	2	Cor Caroli ...	0·06	10·2	0 0 88
17	34	...	...	233	33	> Venus ...	23·55	4049·0	5 0 48
18	31	...	...	232	9	Altair	0·13	22·3	0 0 193
19	38	...	...	186	46	Sirius	1·95	334·8	0 6 274
20	69	1·8*	38	241	18	Sirius	1·72	532·0	0 10 232
				From the additional Observations.					
3	117	3·0	39	206	9	Jupiter	10·09	5207·0	6 7 0
10	42	...	...	208	12	Sirius	0·82	141·2	0 2 347
12	86	1·4	61	223	40	Sirius	1·11	265·9	0 5 114
13	48	1·5	32	216	18	Venus	4·56	1175·0	1 7 109

For future comparisons of the light of shooting-stars, Dr. Heis communicates the following light-ratios of Dr. Seidel, of Munich.

♀ Venus. Mean maximum light $=38·920 \times \alpha$ Lyræ.
♃ Jupiter. „ „ $= 8·237 \times \alpha$ Lyræ.
♂ Mars. „ „ $= 2·935 \times \alpha$ Lyræ.
♄ Saturn (without ring). „ $= 0·466 \times \alpha$ Lyræ.

The mean light of the moon *in any phase* is found from Lambert's formula, $L = \frac{\sin v - v \cos v}{\pi} \times$ *mean maximum light* (v the angular measure of the bright lune, reckoned from the centre of the moon).

The light of the planets, when not at greatest brilliancy, is also found by the formulæ (full moon $=54,816 \times \alpha$ Lyræ),—

$$\text{Light of Venus} \ldots\ldots\ldots\ldots = \frac{\sin v - v \cos v}{(77·8 \times \Delta \Delta')^2} \times \text{full moon};$$

$$\text{Light of Jupiter} \ldots\ldots\ldots\ldots = \frac{\sin v - v \cos v}{(6·61 \times \Delta \Delta')^2} \times \quad „ \quad ;$$

* N.B. The original record 2·0 (re-estimated *vivâ voce* 1·8) was miscorrected 1·0 (see Catalogue).

$$\text{Light of Mars} \;\ldots\ldots\ldots\ldots\; = \frac{\sin v - v \cos v}{(304 \times \Delta\,\Delta')^2} \times \text{full moon};$$

$$\text{Light of Saturn (without ring)} = \frac{\sin v - v \cos v}{(7{\cdot}46 \times \Delta\,\Delta')^2} \times \quad ,, \quad ;$$

where v expresses, as before, the angular measure of the phase, Δ and Δ' the

Erratum in Appendix (V.) to *A Catalogue of Luminous Meteors.* British Association Report for 1863.

In Table III. (p. 330) *for the numbers of the last two columns* read thus.

Table III.

No.		Consumption of coal-gas for luminous effect equal to that of meteor.	Weight of meteoric matter arrested at 30 miles per sec.
		cubic feet.	avoirdupois. oz. grs.
1	....	1·3	0 11
2	....	1·6	0 14
3	....	426·4	8 191
4	....	556·0	14 85
5	....	235·6	4 289
6	....	1·2	0 10
7	....	1·9	0 17
8	....	115·3	2 123
9	....	34·8	0 301
10	....	14·3	0 124
11	....	4·9	0 42
12	....	35·5	0 307
13	....	125·1	2 208
14	....	0·4	0 3
15	....	0·3	0 2
16	....	1·0	0 9
17	....	404·9	8 5
18	....	2·2	0 19
19	....	33·5	0 290
20	....	53·2	1 23
From the additional Observations.			
3	....	520·7	10 131
10	....	14·1	0 230
12	....	26·6	0 122
13	....	117·5	2 142

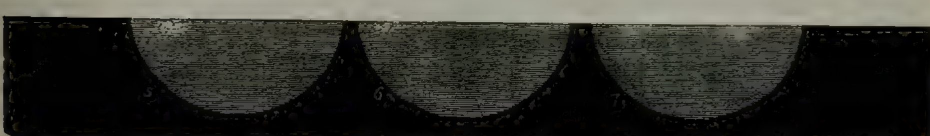


TABLE III.

No.	gth of Path, n miles.	Duration awkhurst).	ocity, miles r second.	Direction of flight. From		Apparent brightness at Hawkhurst	Light of meteor at 1 mile compared	Consumption of coal-gas for luminous effect	Weight of meteoric matter arrested at

Light of Jupiter .... $= \frac{\ldots}{(6{\cdot}61 \times \Delta\,\Delta')^2} \times$,, ;

* N.B. The original record 2·0 (re-estimated *vivâ voce* 1·8) was miscorrected 1·0 (see Catalogue).

Light of Mars .... $= \dfrac{\sin v - v \cos v}{(304 \times \Delta\,\Delta')^2} \times$ full moon ;

Light of Saturn (without ring) $= \dfrac{\sin v - v \cos v}{(7{\cdot}46 \times \Delta\,\Delta')^2} \times$,, ;

where v expresses, as before, the angular measure of the phase, Δ and Δ' the distances from the earth and sun found in the columns of the Nautical Almanack.

(2.) At Münster, Dr. Heis, assisted by his pupils, observed on the evening of the 10th August, 1863—

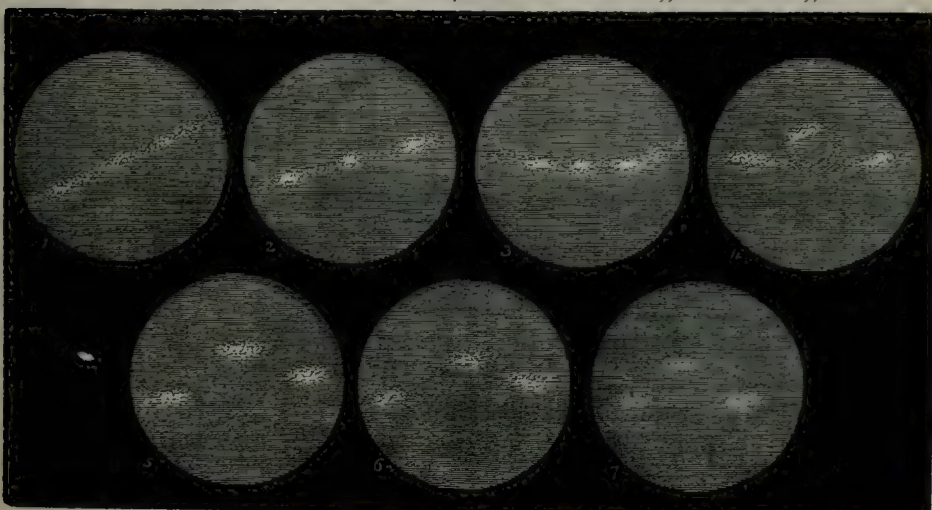
from	9^h P.M.	to	10^h P.M.,	93 meteors.
,,	10 ,,	,,	11 ,,	143 ,,
,,	11 ,,	,,	12 ,,	166 ,,
,,	12 ,,	,,	1 A.M.,	157 ,,
,,	1 ,,	,,	$1\frac{1}{4}$,,	39 ,,

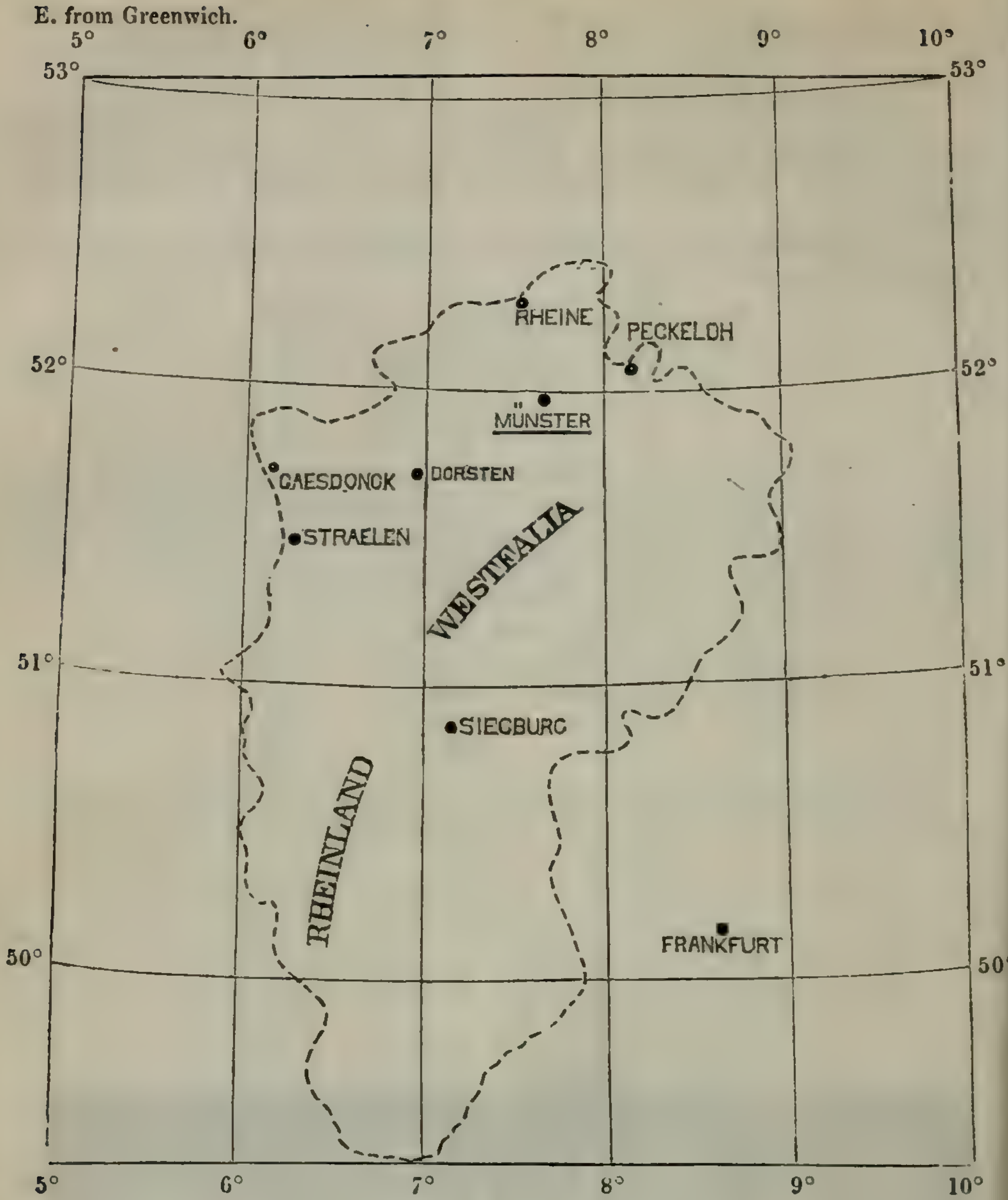
547 of these meteors were drawn upon four lithographed charts of the heavens. According to the custom of Dr. Heis, groups of parallel paths were represented by single lines, to the number of 68. These average courses being transferred to a 30-inch celestial globe and prolonged backwards, indicated, as in former years, the existence of three radiant points.

From	A, $\alpha = 45°$, $\delta = 56°$,	came	250 meteors	$=46$	per cent.
,,	B, $\alpha = 310°$, $\delta = 59°$,	,,	89 ,,	$=16$	,,
,,	N, $\alpha = 15°$, $\delta = 86°$,	,,	87 ,,	$=16$	,,
,,	uncertain Radiants	,,	121 ,,	$=22$	,,
			547	100	

Trains of these meteors (of great permanency) were observed in a comet seeker for nearly three minutes in the following order:—

			h	m	s			
1.	August	9.	9	47	40	= to a 1st mag.*,	train	130 seconds.
2.	,,	10.	9	31	18	= ♀	,,	55 ,,
3.	,,	10.	9	50	35	= ♃	,,	24 ,,
4.	,,	10.	10	38	26	= to a 1st mag.*,	,,	80 ,,
5.	,,	10.	11	8	26	= ♃	,,	43 ,,
6.	,,	10.	12	1	53	= to a 1st mag.*,	,,	168 ,,
7.	,,	10.	12	52	20	= ♃	,,	60 ,,



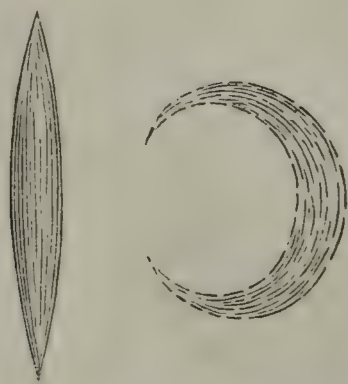


Simultaneous observations were undertaken by M. Heis and his coadjutors

			°	′	″		m	s
at Münster	(M.)	N. lat.	51	58	10;	E. long.	30	31
Peckeloh	(P.)	,,	52	1	0	,,	32	29
Dorsten	(D.)	,,	51	40	0	,,	27	49
Gaesdonck	(G.)	,,	51	40	0	,,	24	30
Straelen	(St.)	,,	51	26	0	,,	24	57
Siegburg	(S.)	,,	50	48	0	,,	29	9
Frankfort-on-Maine	(F.)	,,	50	7	0	,,	34	44
Rheine	(R.)	,,	52	16	0	,,	29	49

The train of No. 6 was at first straight and narrow, and grew gradually wider. It became curved and wound itself into a loop; after separating into fragments it dissolved away.

Similar features to this were observed at Euston Road Observatory, London, by Mr. T. Crumplen. The tail of a meteor at $10^h\ 46^m$ P.M., on the 10th of August, at first was spindle-shaped and 4° or 5° in length. In $4\frac{1}{2}$ minutes it faded gradually away, curving itself until the ends were nearly buckled into a circular form.



The following comparative observations were then collected:—

TABLE IV.

No.	Date.	Hour. Münster mean time.	Station.	Magnitude as per stars.	Train.	First appearance.		End.		Height, in English miles.	
						α=	δ=	α=	δ=	Appearance.	End.
	1863.	h m s				°	°	°	°		
1	Aug. 8	9 38 38	M.	1	With	268	+20	264	+ 4		
			G.	1	With	348	57½	299	10	124	75
2	8	9 42 34	M.	1	With	195	57	205	44		
			G.	1	...	15	80½	269	50½	64	64
3	8	9 43 23	M.	1	With	160	65	190	43		
			G.	...	...	58	69	22	82	39	39
4	8	9 50 32	D.	2	With	170	76	200	54		
			G.	2	...	0	85	248½	76½		
			S.	2	...	138	65	155	55	84	55
5	8	9 54 19	D.	2	With	330	88	240	74		
			G.	4	...	343	70½	319	72½	89	79
6	8	9 53 19	M.	3	...	216	27	213	9		
			G.	...	...	277	64½	261	57	77	25
7	8	10 16 17	M.	2	With	296	12	292	3		
			F.	2	...	127	66	137	56	65	25
8	8	10 23 55	F.	2	...	51	64	59	66		
			G.	2	...	6½	+20½	1½	+ 9	72	53
9	10	9 14 9	M.	♃	With	234	+21	235	−12		
			S.	1	...	200	60	208	+31	106	42
10	10	9 21 51	M.	3	...	324	40	336	23		
			St.	4	...	2	35	338	+28	58	48
11	10	9 24 43	G.	1	...	315	29	291	−14		
			P.	1	...	267	25	255	−17	101	48

TABLE IV. (*continued.*)

No.	Date.	Hour. Münster mean time.	Station.	Magnitude as per stars.	Train.	First appearance.		End.		Height, in English miles.	
						α=	δ=	α=	δ=	Appearance.	End.
	1863.	h m s				°	°	°	°		
12	Aug. 10	9 25 22	M.	2	...	236	34	239	+24		
			G.	1	...	215	50	310	41	65	55
13	10	9 31 14	M.	♀	With	40	55	5	52		
			G.	1	...	17	39½	15	32		
			R.	1	...	5	55	340	30	35	29
14	10	9 42 47	M.	1	With	216	23	213	8		
			S.	1	...	175	52	185	34	58	44
15	10	9 50 35	M.	1	With	33	58	0	65		
			P.	1	...	162	83	238	74	35	25
16	10	9 57 3	M.	2	With	175	54	183	45		
			P.	2	...	217	24	212	8	?	35
17	10	10 7 10	M.	1	With	237	14	233	2		
			G.	...	...	253	11	257	5½		
			S.	...	...	207	38	216	+15	82	51
18	10	10 9 10	M.	1	With	263	5	250	− 8		
			S.	...	...	232	32	235	+13	?	53
19	10	10 12 29	M.	1	With	183	61	194	45		
			S.	1	...	146	65	147	56	101	58
20	10	10 12 52	M.	2	...	275	37	261	26		
			G.	3	...	329	37	315	30	75	55
21	10	10 16 54	P.	♃	With	194	56	190	33		
			G.	1	...	170	75	171	+53	184	65
22	10	10 19 24	M.	2	...	304	1	296	− 7		
			G.	2	...	329	+ 5	320	1½	97	79
23	10	10 32 34	M.	2	...	278	−10	274	19		
			D.	2	...	292	2	286	13	46	23
24	10	10 33 9	M.	1	With	268	10	260	16		
			G.	1	...	308	− 5	297	13½	48	37
25	11	10 50 6	M.	1	With	315	+ 1	312	−10		
			F.	...	...	270	83	238	+65		
			P.	...	...	307	7	304	−15	82	46
26	11	10 52 11	M.	1	With	301	29	286	+18		
			F.	...	...	...	...	...	...	113	46
27	11	10 53 29	M.	2	With	3	10	8	14		
			F.	...	...	51	+56	63	+55	?	55
28	11	11 1 27	M.	1	With	290	−23	280	−23		
			F.	♀	...	244	+14	277	+14	48	42

Average of 28 meteors, August 8th to 10th, beginning 77·9, end 48·3 miles high.

The comparative observations of meteors by telegraph, undertaken between Rome and Civita Vecchia in August 1861, are printed at length in the '*Bulletino Meteorologico*' of the Observatory of the University of Rome, vol. i. for 1862.

The following mean heights are obtained by calculation:—

Average of 19 meteors, August 4th to 8th;	beginning 57·1,	end 46·5	miles high.
„ 23 meteors, August 10th to 11th;	„ 69·4,	„ 56·6	„
Total of 42 meteors, August 4th to 11th;	„ 63·9,	„ 52·1	„

Comparative observations executed in England at the same time afforded the following results:—

Average of 6 meteors, August 6th to 11th; beginning 70·3, end 44·6 miles high.

Hence it appears that the height of shooting-stars in August 1863 was little different from their height in 1861.

(3.) Professor J. Jos. Bianconi of Bologna has addressed the following considerations to the British Meteorological Society, respecting a mechanical theory of the light and heat of luminous meteors advanced formerly by himself in 1839, and recently communicated to the British Meteorological Society. The observations of the luminous trains of meteors conducted by Professor Respighi, Dr. Casoni and himself, in August 1863, have tended to confirm Professor Bianconi in the opinion that heat, partly that of friction, and partly that of compression, is sufficient to volatilize superficial portions of meteorites, so as to produce the rounded edges and erosions of their surfaces, as well as the atmosphere, or halo of light, about the meteors, which remain in a luminous streak upon their track. "Admitting that the heat of friction is sufficiently powerful to maintain the fusion of the surface, the incandescence of the planetoid, and besides this the *sublimation* of the melted matter which goes to form the tail, we see that this feature can only be developed where the heating conditions have the greatest power—namely, near the middle of the flight. It will begin gradually, at first not so ample, becoming very abundant at the middle of the flight, then diminishing again, and just ceasing when the course of the meteor is so slackened as to be incapable of producing the necessary heat....... We find also in the undulated form of the luminous tail of the bolide, the movements peculiar to heated vapours left in the middle of the atmosphere. In short, these few observations lead us to conclude, first, that heat produced, as we are authorized to believe, by friction is not only calculated to produce incandescence and fusion, but that it attains to a higher degree—that of causing a sublimation of the surface-matter of the asteroids, which sublimation or volatilization forms a luminous atmosphere around the falling body, varying in volume according to the intensity of the source of heat; secondly, that this luminous atmosphere left to itself, the tail, disappears partially and by degrees, principally on account of its dimensions, temperature, and density; and that, whilst its particles accumulate concentrically, it contracts and changes its form with the variations peculiar to vapours."

The observation of a large bolide with an enduring streak, on the evening of the 10th of August, 1863, by Professor Bianconi, and Dr. Casoni at Bologna, is noticed in the Catalogue of this Report.

VI. Transactions of the Imperial Academy of Vienna, vol. xliv.

Dr. Julius Schmidt has represented varying phases of the luminous streaks of meteors near the radiant point, on the 10th of August 1860 and 1861. Trains of shooting-stars (visible to the naked eye for two or three seconds) were traced in the field of a telescope for one, two, or even three minutes before they finally disappeared. Points of explosion of the meteors produced stationary clouds of light; but intermediate lines of the train moved in various figures with looped curves to a distance from the stationary points. Train-fragments were observed to separate from one another three degrees in three minutes of time.

VII. American Journal of Science and Art, vol. xxxvi. July 1863.

"Remarks on the luminosity of meteors as affected by latent heat," by Benjamin V. Marsh, Philadelphia.

Mr. Marsh presents in a tabular view the *heating power* of a constant volume of air drawn from different heights in the atmosphere, upon an equal volume of air at standard pressure, when the latent heat is rendered sensible by condensation of the air to standard pressure. The results of Mr. Marsh are here reproduced.

Height in miles. (n) being equal to the No. of the terms of this series.	Dilatation. Number of volumes corresponding to one volume at the surface of the earth.	Heating power of 1 volume (upon 1 volume of standard pressure), *when condensed to standard pressure.*
na.	2^n.	$\frac{2^n-1}{2^n}\times 143°$.
3·43	2	72°
6·86	4	107
10·29	8	126
13·72	16	135
17·15	32	139
20·58	64	142
24·01	128	143
27·44	256	143
30·87	512	143
34·30	1024	143
37·73	2048	143
41·16	4096	143
44·59	8192	143
48·02	16384	143
51·45	32768	143
54·88	65536	143
58·31	131072	143
61·74	262144	143
65·17	524288	143
68·60	1048576	143
102·90	1073741824	143
137·20	1099511627776	143
171·50	1125899906842624	143
205·80	1152921504606846976	143

The *bulk* of air compressed before a meteorite, determines the absolute quantity of heat made sensible, independently of the height of the trajectory above the surface of the earth, until the height of twenty-four miles is reached in the descent. From this point the quantity of heat made sensible gradually diminishes, and falls rapidly to half the quantity of the supreme heights, between ten miles and three miles above the earth's surface.

Mr. Marsh points out the intense illumination which a uniform development of free heat must produce in the highest strata of the atmosphere. At

a lower elevation the meteor, in the words of M. Quetelet, "will have entered a medium which has not the elements necessary to its continued brilliancy;" for here the potential heat extracted in a given tract of the meteor's flight suffers a rapid decrease, and the density of the air to be ignited, a sudden increase upon the values of these quantities in the higher regions of the atmosphere. Mr. Marsh produces no evidence that the pressure encountered by a meteorite in its flight through the air is in reality constant, in the manner supposed in this explanation.

VIII.

An exceedingly brilliant meteor appeared over the United States of America on the 6th of August 1860, at 7^h 38^m P.M., New York mean time, about five minutes after sunset. Professor Newton has estimated the path of this meteor at 225 or 250 miles in length, accomplished with a geocentric velocity of eighteen miles per second, from thirty-nine miles over the southern line of Pennsylvania to thirty-six miles high, W. or N.W. of Buffalo. Corrected for terrestrial attraction, the geocentric velocity is 16·6 miles per second, and the heliocentric velocity 30·4 miles per second towards R. A. 67° 45′, N. Decl. 33° 25′.

The hyperbolic elements of this meteor cannot be reduced to elliptic elements of its orbit by any but the largest corrections applied to the individual observations.

IX. 'Physique du Globe,' by M. Ad. Quetelet (Brussels, 1861).

In a chapter devoted to shooting-stars, M. Quetelet describes the combined observations organized by himself in 1824 at Brussels, to determine the velocities of shooting-stars. Up to that time, only five instances existed where the velocities of shooting-stars had been determined, and M. Quetelet added six cases to the number. Their average velocity was seventeen miles per second. This velocity is planetary, but Benzenberg continued to maintain that shooting-stars migrated from the moon.

M. Quetelet first drew attention to the prevalence of shooting-stars upon the 10th of August, on the occasion of an observation reported by M. Sauveur, at the Session of the Roy. Acad. of Brussels, 1836, Dec. 3rd*.

The late E. C. Herrick, at Newhaven, U.S., made an independent announcement of the same date in the American Journal of Science (vol. xxxiii. p. 176), on the occasion of an accidental view of the phenomenon in 1837.

The 2nd January, 15th October, and 7th December are characterized by M. Quetelet as favourable for the return of star-showers, and his Catalogue of similar phenomena has been made the subject of important conclusions by Professor Newton (Appendix No. IV.).

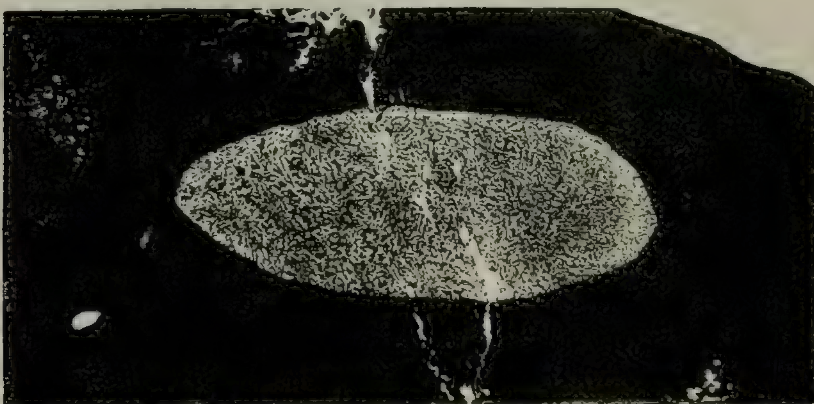
X. A New British Meteoric Iron (*Edinburgh New Philosophical Journal, New Series, for July* 1862).

A new British meteoric iron, the second hitherto discovered, has been analyzed by Dr. Murray Thomson, and described by Dr. J. A. Smith, of the Royal Physical Society of Edinburgh. The meteorite was excavated, in 1827, from a bed of firm clay 4 feet below the surface, in the village of Newstead,

* In England this date was noticed in the Philosophical Magazine for 1821 (p. 347), by Mr. John Farey, in a remarkable series of questions concerning shooting-stars. Mr. T. Forster devoted the date to a short discussion on shooting-stars in his volume of the 'Perennial Calendar,' published in England in 1824.

near Melrose, Roxburghshire. The mass, $32\frac{3}{4}$ lbs. in weight, was preserved upon the spot until 1861, when it was subjected to examination by Dr. Alexander Smith in Edinburgh, with results which prove the meteoric nature of the mass. In size and figure the meteorite is $10\frac{3}{4}$ inches in length, consisting of a warty mass $1\frac{1}{2}$ foot in girth, joined to an acuminated extremity, unlike any manufactured metal, but suggesting the idea that the extremity which is now the smaller and more pointed first reached the earth in its descent, while the larger extremity shows the part least affected by the shock. Casts and photographs having been taken, the meteorite was divided longitudinally into two portions by the saw. The surfaces were filed and polished, and the figures of Widmanstätten were developed by the action of nitric acid.

Fig. 1.



These are more minute than in the generality of aërosiderites, but attest the meteoric character of the mass. Under the pressure necessary for taking a wax impression (whereof figure 1 is an electrotype copy), the smaller half of the mass separated into two portions. Such veins of separation are not uncommon among meteoric irons. The specific gravity of the lobed fragment was found to be 6·1919, that of the pointed fragment 6·7400. The difference in hardness between the centre and outer layers of the metal was easily perceived by the use of the graving tool, and may be explained by the effects of sudden cooling, especially at the point, from contact with the surface of the earth.

The specific gravity of the whole mass was 6·517, that of the unbroken half being 6·499. Transverse slices of the lobed portion and of the pyra-

Fig. 2.

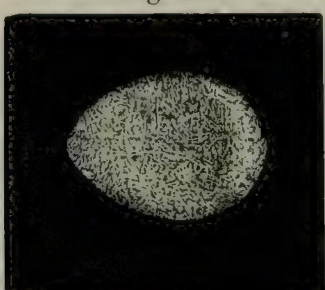
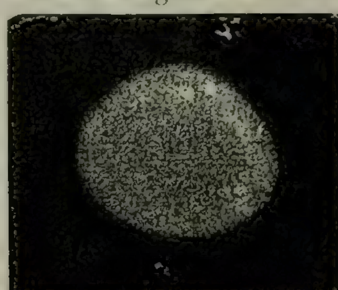


Fig. 3.



midal portion yielded respectively the specific gravities 6·350 and 6·750. The etching, fig. 3, demonstrates the closer grain of the iron near the pointed

extremity, and fig. 2 the crystallization near the middle of the rounded portion of the mass. The iron, especially at the pyramidal part, is very brittle: so much so, that no difficulty is experienced in reducing a fragment from this part of the meteorite to powder in an iron mortar.

From an analysis of from 60 to 70 grains of filings of the iron obtained in the first process of dissection, Dr. Murray Thomson obtained the following proportions:—

Iron	93·51	per cent.
Nickel	4·86	,,
Silica	0·91	,,
Carbon........	0·59	,,
	99·87	,,

Fragments were also examined separately, for carbon and for silica, with the following results:—

Carbon........	0·56	per cent.
Silica	0·90	,,

agreeing closely with the preceding analysis.

Portions of this meteoric iron, with a plaster cast of the entire mass, are preserved in the Natural History Museum of Edinburgh. The principal part is deposited in the Collection of the British Museum.

Fourth Report of the Committee on Steamship Performance.

Contents.

"The object of the Committee is to make public such recorded facts through the medium of the Association, and being accessible to the public in that manner, to bring the greatest amount of science to the solution of the difficulties now existing, to the scientific improvement of the forms of vessels and the qualities of marine engines. They will especially endeavour to guard against information so furnished to them being used in any other way, and they trust they may look for the cooperation of Members of Yacht Clubs having steam

yachts, of shipowners, as well as of steamship builders and engineers."—*Third Report*, 1861, p. 16.

At the meeting of the British Association held at Cambridge in 1862 the Committee were reappointed, and the following noblemen and gentlemen were nominated to serve on the Committee:—

The Duke of Sutherland.	Hon. Captain Egerton, R.N.
The Earl of Gifford, M.P.*	Hon. Leopold Agar Ellis, M.P.
The Earl of Caithness.	J. E. McConnell, Esq., C.E.
The Lord Dufferin.	Wm. Smith, Esq., C.E.
Wm. Fairbairn, Esq., LL.D., F.R.S.	Professor J. M. Rankine, LL.D.
J. Scott Russell, Esq., F.R.S.	J. R. Napier, Esq.
Admiral E. Paris, C.B. (Imperial French Navy).	R. Roberts, Esq., C.E.
	Henry Wright, Esq., Secretary.

With power to add to their number.

The following noblemen and gentlemen, having consented to assist your Committee, were, during the present year, elected as corresponding members:—

Lord C. Paget, M.P., C.B.	Captain Robertson, R.N.
The Earl of Durham.	Captain Sulivan, R.N., C.B.
The Marquis of Hartington, M.P.	Captain Mangles.
Viscount Hill.	T. R. Tufnell, Esq.
Lord John Hay.	Wm. Froude, Esq.
Admiral Elliott.	W. Just, Esq.
Captain Hope, R.N.	John Elder, Esq.
Captain Ryder, R.N.	David Rowan, Esq.
Robert Dalglish, Esq., M.P.	J. McF. Gray, Esq.

Your Committee have the pleasure of stating that, at the unanimous request of the members of the Committee, his Grace the Duke of Sutherland undertook the office of Chairman.

Your Committee have pleasure in reporting satisfactory progress, and that they have had an increasing amount of useful information placed at their disposal. Much greater interest is now taken in the objects of the inquiry, and a still increasing number of observers have adopted the forms of the Committee, for recording the performances of vessels.

The importance of the information collected by your Committee is attracting the attention of steamship owners, as well as scientific investigators; and it is hoped the result of greater efficiency and economy in the application of steam, as well as improvements in the construction of steam-vessels, will be the result of these Reports; and your Committee have reason to believe that considerable advantages have already been derived from their labours by steamship owners.

The future Publication of the Returns of Steamship Performance.—This subject has seriously engaged the attention of the Committee. The question has been raised, whether the continuance of the Publication ought to take place in the Transactions of the British Association, or whether it should be made through the medium of some publication of a more strictly mechanical nature, and more widely circulated among professional engineers and shipbuilders. The Committee are unanimously of opinion that these Returns should be continued and extended, and that they should both be preserved and published.

The collection of these Returns is a matter now so completely organized

* Since deceased.

that it has ceased to cause either labour or occupation to the Committee. A single officer can readily perform the work of collection, and it seems that nothing further is required from the British Association for the future than such an annual grant as would serve to compensate the collecting officer and ensure the publication of the information obtained.

Exact Records of Qualities and Performance of War Steamers.—It is well known to members of the British Association, that one of the chief objects in the original appointment of this Committee was to induce the Lords of the Admiralty to take the steps necessary to obtain such exact scientific data as should serve for the determination of true principles to be used in the design and construction of steam fleets. For this purpose exact observations are necessary to be made with fitting instruments, specially constructed, upon steamships of large size, in smooth water and rough, laden and light, towing and being towed, going slow and going quick, with clean bottoms and with foul, under predetermined varieties of condition. Such exact experiments are essential to the promotion of the science of naval construction, and can only be made by the naval service of the country, for whose special benefit they are designed. The British Association has freely, for many years, expended its own funds for this great national purpose, and it only applied to the Admiralty when their own exertions could not accomplish anything further without aid.

The Committee report, with deep regret, that all their exertions, repeated year by year, have failed to move their lordships to collect a systematic series of scientific data of this sort, either for the use of their own officers, who ardently desire such professional information, or for the use of science at large; the only objection they state being that such knowledge would cost money, and that they do not think fit to authorize the necessary expenditure.

The Committee have, therefore, to report that this portion of their mission has entirely failed, and they think they could render no service to science by any further communication with the Admiralty on a matter which seems hopeless.

The annexed correspondence will show how they have done their duty, and how the Admiralty have met them:—

"BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE. COMMITTEE ON STEAMSHIP PERFORMANCE.

"*Memorandum with reference to the third Resolution of the British Association Committee on Steamship Performance, at a Meeting held at Stafford House, on the 5th June,* 1863, *his Grace the Duke of Sutherland in the Chair*; *namely,*

"That the Chairman be requested to communicate to the First Lord of the Admiralty the strong desire which is felt by the members of the British Association for the Advancement of Science to obtain certain scientific data by exact experiments upon powerful and large steamships, and which it is impossible to obtain by other means than those at the command of the Admiralty."

The Committee, having now carried on their labours systematically during several years, have collected a large number of records of the practical performances of steamships at sea, which the British Association have published annually in their Transactions, and which have been acknowledged by many of the large steamship companies to be of material use to them in improving the service and economy of their ships.

But there remain very important facts to be determined, which can be obtained by direct experiment only, and which only the Admiralty can procure. These facts are wanted as data for the scientific construction of future ships. At present each shipbuilder, or designer of ships, is obliged to construct them from the limited number of elements he may have been able to obtain from his personal experience. What is wanted is that these data should be obtained from experiments made publicly and on a national scale, so as to give general and entire confidence in the results, and so that they might be accepted as data for naval construction in all time to come.

The experiments required for this purpose are of the following nature:—

I.—Experiments on actual stability in still water; or exact measures of angles of keel at various degrees of immersion. It would be well that these should be made under the following four conditions:—

1. When the ship is launched.
2. When she is completed with her machinery, but empty.
3. When she is armed and equipped.
4. With her seagoing complement of stores.

II.—Experiments on the time and angles of oscillation of a ship in still water, under the same four conditions.

III.—Experiments on the measure of resistance of one ship towed by another, under the same four conditions.

IV.—Experiments on the same ship when propelled under the last three of the four conditions, by her own machinery, at the same speed as when towed.

V.—Experiments relating chiefly to the machinery and the propeller.

1. The exact measures of steam power developed in the engine.
2. Exact measures of the power expended by the engines.
3. Exact measures of the direct propelling force of the screw.
4. Exact measures of the power applied to turning the screw.

VI.—Experiments

1. On a vessel with her bottom foul from her voyage.
2. The same vessel with that foulness removed.
3. The same vessel polished as finely as possible.

VII.—A careful series of records of the same vessel at sea, her inclination under sail, her times of oscillation on the waves, the speed and nature of the waves, the force of the wind, and the performance of the engines and boilers.

If all this could be done on one of the largest ships of the newest class, more valuable information could be obtained than has ever yet been ascertained in the history of the world.

His Grace the Duke of Sutherland, the Chairman, having submitted the preceding suggestions to His Grace the Duke of Somerset, First Lord of the Admiralty, the following reply was received:—

"Admiralty, 7th July, 1863.

"Gentlemen,—My Lords Commissioners of the Admiralty having had under their consideration the memorandum of the Committee on Steamship Performance, drawn up at the meeting held at Stafford House on the 5th of last month, I am commanded to acquaint you that their lordships are of opinion that experiments could only be satisfactorily made to ascertain the stability, oscillations, and resistance of large ships under the various conditions specified under clauses 1, 2, 3, and 4, by appropriating a ship expressly for the purpose; and their lordships regret to say that they could not undertake the

carrying out of such experiments, which must necessarily occupy much time and entail considerable expense.

"I am at the same time to observe that some of the experiments proposed as to the stability of ships, and as to the time of their periodic rolling in still water, are now in progress, and will be communicated to the Committee. Others again are published from time to time in the tables of results of trials of ships, from which nearly all the practical information sought may readily be deduced.

"I am, Gentlemen,
"Your very humble Servant,
"C. Paget."

"*To the Members of the Committee of the British Association on Steamship Performance.*"

The Royal Navy.—Although the Admiralty declined to accede to the request of the Committee to obtain the valuable experimental information requested for the advancement of the science of naval architecture, they have continued to allow their officers to furnish the usual returns of performance of Her Majesty's ships. Numerous scientific officers connected with H.M.'s steam department continue to furnish valuable returns, and the chief engineers of several of Her Majesty's steamships have continued their interesting records; a selection therefrom is appended to this Report, together with two sheets of Indicator Diagrams of Her Majesty's steamship 'Victor Emmanuel.'

The Royal Mail Companies.—The West India Mail Company, the Peninsular and Oriental Company, the Pacific Royal Mail Company, the Dublin and Holyhead Company, all continue the system of recording their performances in the way recommended by the Committee; a selection from some of these records has been made by this Committee, and will be found in the Appendix.

Foreign Mail Companies.—The large fleet of the Messageries Impériales continue to forward the record of their performances in the manner originally commenced by M. Behic, as managing director of this important Company, and now Minister of Public Works in France. The returns of this Company (in continuation of those given in the third Report) for the years 1861 and 1862 are appended. The Austrian Lloyd's Company also continue to forward the record of the performances of the vessels composing their fleet, through the kind offices of Col. Paradis and M. Otto Dingler.

The Mercantile Marine Service.—The Committee, to meet the wishes of certain steamship owners, issued a new form of steam log, to be kept by marine engineers (the name of each vessel being indicated by a letter of reference, a corresponding list being kept by the owners, and the name of any vessel only to be given up by their consent). The Committee are happy to say that that issue has produced valuable records of eleven steamships, of which they now publish a systematic abstract.

A continuation of the engineer's logs of the 'Great Eastern,' as also a general summary thereof, will be found in the Appendix.

Your Committee recommend that the thanks of the British Association be given to the various gentlemen who have contributed returns during the present year, for their services to science and their assistance to this Committee in organizing observations, and express a hope that some method may be devised of continuing the publication of the system of records now so well organized by this Committee; and that some other body than our Admiralty may be found willing to afford those means of advancing the science of naval architecture, which they refuse.

The sum voted to this Committee by the Association (£100) has been expended, and it is anticipated the expenses will be slightly in excess of the sum granted; but as all the accounts had not been received, the exact statement could not be prepared in time for the Meeting.

Your Committee, in conclusion, have the painful duty of recording the death of the Earl of Gifford, who was an active and estimable member of the Committee. (Signed) SUTHERLAND,
Chairman.

Offices of the Committee,
19 Salisbury Street, Strand, London, W.C.

APPENDIX.

City of Dublin and Holyhead Company's Returns.

The following particulars relative to the four vessels employed on the mail service between Dublin and Holyhead were embodied in a paper read before the Institution of Civil Engineers, last year, by Mr. W. Watson, Managing Director of the City of Dublin Steam Packet Company; and will be read with interest in connexion with the Tables of the performances of the 'Ulster' and 'Munster,' which are appended, and also with reference to the Tables which have been given in preceding Reports.

London and Dublin Communication.—The London and North-Western Railway Company and the City of Dublin Steam Packet Company having agreed to united action, passed a Bill through Parliament, in 1855, to sanction and facilitate their arrangements.

The Government then made a communication to the Companies, as to the requirements of the Post Office for two services, one by day and the other by night, to be completed in half an hour less time than that which had been already proposed, and this to be guaranteed under heavy pecuniary penalties for every minute of excess, arising from causes even beyond control. The Companies agreed to undertake this service, but altogether declined to submit to penalties for loss of time arising from fogs or other causes wholly beyond their control. The subject having been allowed to lie dormant for another year, the Members of Parliament for Ireland collectively urged on the Prime Minister so forcibly the expediency and necessity for providing for the improved means of communication at the public expense, as had been formerly done when the new Holyhead Road and Telford Bridges were constructed, that the matter was at last taken up seriously, and the Government agreed to carry into effect the plan recommended in 1853, and which eventually received the cordial approval of the Lords of the Treasury.

The main provisions of the new postal contract were, first, that the entire distance between London and Kingstown was to be performed in eleven hours (eleven hours and a half being allowed to Dublin), assigning four hours for the sea passage, subject to fines for loss of time, unless arising from weather or other causes beyond control; secondly, that four steam packets should be provided, each 300 feet in length and 1700 tons burthen builder's measurement, with engines of 600 nominal horse-power; thirdly, that express trains should be appropriated exclusively to the Irish traffic; and fourthly, a morning and evening departure from each capital. The Improved Service was arranged to be commenced in January 1861, two years being allowed by the contract for building the vessels.

TABLE 2.

ABSTRACT OF THE LOG OF THE PACIFIC STEAM NAVIGATION COMPANY'S ROYAL MAIL STEAMSHIP "QUITO," P. S. HOLLOWAY, Commander, FROM LIVERPOOL TOWARDS ST. VINCENT, COMMENCED AT 3.13 P.M., 27TH JANUARY, 1864, AND ENDED AT 6.45 A.M. 6TH FEBRUARY, 1864

Days.	Draught of Water. Forward.	Draught of Water. Aft.	Winds.	Courses.	Distances.	Latitude.	Longitude.	Pressure of Steam.	Coal Consumed.	Oil, Gallons.	Tallow, lbs.	Waste.	Mileage. Wheels.	Mileage. Ship.	Mileage. Slip.	Revolutions per Hour. Day.	Revolutions per Hour. Minute.	Miles per Ton.	Temperature. Sea.	Temperature. Feed.	Temperature. Engine Room.	Vacuum.	Remarks.
Jan. 28	ft. in. 12 3	ft. in. 12 6	S.W.	Various	201	° ′ 51 47N	° ′ 7 2W	34	34	11	40	4	279	201	28·8	24,606	20	...	44	125	90	28	Jan. 28. Strong W. winds and thick cloudy weather; midnight, thick cloudy weather; ship pitching heavily, shipping much water.
29	...	...	S.	S20, 6W	260	47 27N	9 47W	34	27	6	25	4	379	276	31·00	31,789	22	10·3	50	130	93	28	Jan. 29. Do. with heavy sea; ship pitching heavily; do. strong breeze.
30	...	...	S.E.	S10, 11W	295	43 43N	12 4W	34	27	7	18	4	378	293	28·00	33,375	23	10·6	56	135	96	28½	Jan. 30. Fresh winds and cloudy, with heavy westerly swell.
31	...	...	S.E.	S26, 4W	315	38 6N	15 0W	34	30	7	20	4	380	315	22·2	33,364	23·25	10·6	64	140	100	27½	Jan. 31. Do.
Feb. 1	...	...	S.S.E.	S15, 30W	293	33 19N	16 45W	34	31	7	20	4	381	300	23·5	34,301	23·5	10·00	68	140	102	27½	Feb. 1. Do. breeze and fine.
2	...	...	S.S.E.	S18, 13W	293	28 44N	18 31W	33	30	7	20	4	379	300	21·00	33,455	23	10·00	70	140	106	27½	Feb. 2. Do. do. 10.50 a.m. observed Porto Santo Island; 3.30 p.m. off the Port of Madeira showed our number, distance 5 miles.
3	...	...	Variable	S23, 57W	207	24 12N	20 46W	33	30	7	20	4	260	207	19·5	32,453	22·30	9·8	70	145	109	27½	Feb. 3. Do. winds and cloudy weather.
4	...	...	Do.	S38, 49W	268	20 1N	23 3W	32	30	7	21	4	353	268	19·00	31,137	21·75	8·0	71	150	108	27	Feb. 4. Variable and fine.
5	10 3	11 4	...	S31, 34W	219	At St.	Vincent	31	24	5	24	0	274	219	20·0	24,004	21	9·1	72	160	108	27	Feb. 5. Do. 2.30 observed St. Antonio ½ point on starboard bow, weather being hazy; laid to until daylight; 5.30 went on full speed; 6.45 anchored at St. Vincent; engines working well. Burning Scotch coal from first until arrival at St. Vincent.
					2,486				263	64	111	41											
									3	6	0	-											
									266	70	220	41											

R. MILLER, Chief Engineer.

	Coal consumed.	Oil, gallons.	Tallow, lbs.	Waste.
Stores on board	341	558	1,555	250
Consumed between Liverpool and St Vincent	70	220	41	—
Stores remaining at St. Vincent	—	338	1,335	209

TABLE 1.—ENGINEER'S LOG OF CITY OF DUBLIN STEAM PACKET COMPANY'S STEAMSHIP "MUNSTER," JUNE AND JULY, 1863

Date.	Time on Passage.	Revolutions per minute.	Steam.	Vacuum.	Grade of Expansion.	Coals.	Engine oil.	Tallow.	Lamp [illegible]	[illegible]	[illegible]	Remarks.
June 13, p.m. ...	3·36	21	19	26	1st	50	2½	10	...	4500	285	Fresh breeze.
June 14, a.m. ...	3·36	21	18	26½	1st	...	2½	10	...	4562	285	Fresh breeze.
June 14, p.m. ...	3·36	21·34	20	26	1st	45	3½	15	...	4611	293	Fresh breeze.
June 15, a.m. ...	3·41	20·48	17	26	1st	...	½	10	...	4618	280	Fresh breeze, heavy swell.
June 15, p.m. ...	3·40	20·73	18	26	1st	50	3½	10	...	4686	280	No draft.
June 16, a.m. ...	3·45	20	17	27	1st	...	½	10	...	4512	285	No draft, small coals
June 16, p.m. ...	3·42	20·03	19	26	2nd	50	3½	15	...	4647	290	Fresh breeze.
June 17, a.m. ...	3·43	20·6	16	27	2nd	...	1½	10	...	4578	270	Fresh breeze.
June 17, p.m. ...	3·49	20·92	20	27	2nd	50	3½	15	...	4791	285	Fresh breeze.
June 18, a.m. ...	3·40	21	20	27	2nd	...	½	10	...	4646	285	Mild.
June 18, p.m. ...	3·49	20·37	20	26	2nd	45	4½	10	...	4665	280	Very foggy.
June 19, a.m. ...	6·17	12	18	27	4th	...	½	10	...	4502	270	Dense fog, going easy all the passage.
June 19, p.m. ...	3·45	20·05	19	26½	2nd	45	4½	10	...	4714	290	Mild.
June 20, a.m. ...	3·43	21·16	16	26	2nd	...	½	10	...	4697	285	Mild.
June 20, p.m. ...	3·50	20·29	18	27	2nd	45	4½	10	...	4698	280	Foggy; eased 21 minutes.
June 21, a.m. ...	3·40	21	18	27	2nd	...	½	10	...	4631	285	Mild.
June 21, p.m. ...	3·52	20·13	17	27	2nd	45	4½	15	...	4740	275	Mild.
June 22, a.m. ...	4·37	17	18	27	...	...	½	10	...	4771	270	Dense fog; eased at six o'clock; going at 14 revolutions till arrival at Kingstown.
June 22, p.m. ...	5·35	13·5	15	27	...	45	3½	10	...	4532	260	Fog from eight till 12.10; going at 12 revolutions per minute.
June 23, a.m. ...	4·13	18·4	16	27	...	...	1½	10	...	4658	250	Fog; eased at 6.30; stopped seven times.
June 23, p.m. ...	3·53	19·79	16	27	2nd	40	3½	10	...	4611	255	Mild; small coals.
June 24, a.m. ...	3·47	19·97	17	27	2nd	...	½	...	...	4530	275	Mild.
June 24, p.m. ...	3·50	20	16	27	2nd	40	4½	10	...	4635	275	Fresh breeze.
June 25, a.m. ...	3·47	19·71	16	27	2nd	...	½	10	...	4470	275	Fresh breeze.
June 25, p.m. ...	3·50	20	11	27	2nd	45	4½	15	...	4596	270	Fresh breeze; light swell; small coals.
June 26, a.m. ...	3·45	20	16	27	2nd	...	½	10	...	4504	265	Mild.
June 26, p.m. ...	3·41	20·74	16	27	1st	45	3½	10	...	4585	270	Fresh breeze, North East; bad coals.
June 27, a.m. ...	3·40	20·66	16	27	1st	...	½	10	...	4547	270	Fresh breeze.
June 27, p.m. ...	3·30	21·48	20	26	1st	45	3½	10	1	4571	285	Mild.
June 28, a.m. ...	3·36	21	20	26	2nd	...	½	10	...	4572	270	Mild.
June 28, p.m. ...	3·31	21·48	20	26	1st	45	3½	10	...	4533	260	Mild.
June 29, a.m. ...	3·39	21·18	20	26	2nd	...	1½	10	...	4640	280	Fresh breeze; light swell.
June 29, Noon...	3·41	21	20	26	1st	24	2	10	...	4678	275	Fresh breeze; light swell; return empty.
July 6, p.m. ...	3·37	21	19	26	2nd	65	5½	10	...	4572	285	Running the Day Mails; taking in all coals at Holyhead.
July 7, a.m. ...	3·41	21	20	26	2nd	...	½	10	...	4674	290	
July 7, p.m. ...	3·42	20·66	18	26	2nd	60	4½	10	...	4588	280	Mild.
July 8, a.m. ...	3·40	21	19	26	2nd	...	½	10	...	4660	290	Mild; foggy.
July 8, p.m. ...	3·38	21	20	26½	2nd	55	3½	10	...	4582	295	Mild.
July 9, a.m. ...	3·39	21	20	26	2nd	...	½	10	1	4640	275	Mild.
July 9, p.m. ...	3·37	20·76	19	27	1st	50	2	10	...	4505	275	Fresh breeze.
July 10, a.m. ...	3·41	20·84	19	26½	2nd	...	½	10	...	4607	290	Mild.
July 10, p.m. ...	3·43	20·74	19	26½	2nd	50	2½	10	...	4625	295	Mild.
July 11, a.m. ...	3·39	21	20	26	2nd	...	½	10	1	4620	290	Mild.
July 11, p.m. ...	3·42	20·94	19	26	1st	50	3½	10	...	4649	290	Fresh breeze; light swell.
July 12, a.m. ...	3·45	20·76	20	26½	1st	...	½	10	...	4701	275	Fresh breeze; heavy swell.
July 12, p.m. ...	3·38	20·89	20	26½	2nd	55	3½	10	½	4565	290	Light breeze.
July 13, a.m. ...	3·40	20·73	20	26	2nd	...	½	10	1	4659	270	Fresh breeze.
July 13, p.m. ...	3·39	20·66	20	26½	2nd	50	3	10	...	4633	280	Fresh breeze.
July 14, a.m. ...	3·41	20·96	20	26½	2nd	...	½	15	...	4634	285	Fresh breeze; long swell.
July 14, p.m. ...	3·46	20·34	18	27	2nd	50	3½	10	...	4567	285	Moderate.
July 15, a.m. ...	3·35	21·22	20	26½	2nd	...	½	10	...	4564	275	Moderate.
July 15, p.m. ...	3·45	20·84	19	26	2nd	50	3½	15	...	4691	285	Moderate.
July 16, a.m. ...	3·41	21	20	26½	2nd	...	½	10	1	4658	290	Moderate.
July 16, p.m. ...	3·49	20·78	20	26	2nd	55	3½	10	...	4760	275	Moderate.
July 17, a.m. ...	3·44	21	20	26	1st	...	½	10	1	4716	275	Fresh breeze; heavy sea.
July 17, p.m. ...	4·5	20	20	26½	1st	55	3½	10	...	4959	285	Fresh breeze; heavy sea.
July 18, a.m. ...	3·50	20·72	19	26	1st	...	½	10	...	4768	290	Fresh breeze; long swell.
July 18, p.m. ...	3·53	20·67	20	26½	1st	60	3½	10	...	4900	295	Fresh breeze; long swell.
July 19, a.m. ...	3·46	21	20	26½	1st	...	½	10	1	4772	270	Light breeze; long swell
July 19, p.m. ...	3·43	21	20	26½	1st	55	3½	10	...	4684	275	Moderate.
July 20, a.m. ...	3·44	21	20	26	1st	...	½	10	...	4723	280	Moderate.
						1514	132	635	8½			

TABLE 3.—ROYAL (WEST INDIA) MAIL PACKET COMPANY.—SOUTHAMPTON TO ST. THOMAS, DISTANCE 3622 MILES

Date of Departure.	Name of Ship.	Tonnage, Builder's measurement.	No. of voyage.	Time of Passage in Hours, deducting Stoppages.	Coals consumed on Passage, in Tons.	Mean consumption per Hour, in Cwts.	Mean Speed per Hour, in Knots.	Mean Displacement, in Tons.	Co-efficient of Performance.	Condition of Hull, whether clean, ordinary, or foul.	Description and Quality of Coal, whether good, ordinary, or bad.	State of Weather during Voyage, whether favourable or unfavourable. Hours Sail Set. Square.	Hours Sail Set. F. & A.	No. of Hours on each Grade of Expansion. Full Steam.	1st Grade.	2nd Grade.	3rd Grade.	4th Grade.	5th Grade.	Consumption of Stores. Oil in Gallons.	Tallow in lbs.	[illegible]	Waste in lbs.	Name of Chief Engineer.
1862. July 2nd	Atrato	......	44	330	1161	68½	10½	4067	1613	Ordinary	Good .	49	146		120	84	118			18 / 78	24 / 140	19 / 10	160 / 120	D. Brown
July 17th	Shannon	......	15	325	1153	70½	11½	4845	5572	Clean	Do.	[illegible]	[illegible]	103	150	[illegible]	[illegible]			11 / 134	[illegible]	11	111 / [illegible]	J. Walker
August 2nd	Seine	......	13	343	1209	70½	10½	4026	4753	Foul	Do.	54	[illegible]		315	24				21 / [illegible]	28 / [illegible]	13 / 1	180 / 147	J. Grubb
August 17th	Tasmanian	......	13	329	1011	61½	11	3701	6178	Ordinary	Do.......	[illegible]	120½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	24 / [illegible]	[illegible] / 170	[illegible]	[illegible]	A. Wyle
September 2nd	Atrato	......	45	338	1153	68	10¾	4100	4518	Foul	Do........	20	163		105	[illegible]	[illegible]			14 / 70	18 / [illegible]	[illegible]	[illegible]	D. Brown
September 17th	La Plata		[illegible]	[illegible]	1171	[illegible]	10½	4019	4078	Ordinary	Fair	103	[illegible]	21	21	72	73	18		[illegible] / 119	11 / [illegible]	[illegible]	[illegible]	A. M[illegible]
October 2nd	Seine	......	14	338	1018	60½	10¾	5091	5837	Clean	Good	[illegible]	111	[illegible]	[illegible]	114	[illegible]	[illegible]	33	18 / [illegible]	[illegible]	[illegible]	212 / [illegible]	J. Grubb
October 18th	Tasmanian		11	[illegible]	1000	[illegible]	10½	3501	1360	Do. .	Do.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible] / 111	[illegible]	[illegible]	[illegible]	A. Wyle
November 3rd ...	Atrato	......	46	326	1190	73	11½	4100	4831	Do	Do.	[illegible]	[illegible]	15	[illegible]	[illegible]	72	[illegible]		18 / [illegible]	[illegible]	[illegible]	[illegible]	D. Brown
November 17th	Shannon	......	16	325	1174	72½	11½	6014	6682	Do.	Do.	[illegible]	182	[illegible]	[illegible]					51 / [illegible]	81 / [illegible]	[illegible]	[illegible]	J. Walker
December 2nd	Seine		15	[illegible]	[illegible]	[illegible]	10½	4975	4448	Ordinary	Do.	[illegible]	[illegible]	21	[illegible]					[illegible]	11 / [illegible]	[illegible]	[illegible]	J. Grubb
December 17th	Tasmanian		15	[illegible]	[illegible]	[illegible]	10¾	3697	5168	Do.	Do.	[illegible]	[illegible]	[illegible]	[illegible] / 17	17	[illegible]	13 / 9 / 5 / 2	[illegible]	11 / [illegible]	[illegible] / 187	[illegible]	[illegible]	A. Wyle
1863. January 2nd	Atrato	......	47	350	1243	71	10¾	4029	3993	Do. ...	Do......	[illegible]	[illegible]	[illegible]	9	[illegible]	21	[illegible]		[illegible] / 81	[illegible]	11	[illegible]	D. Brown
January 17th	Shannon	......	17	375	1288	68½	9½	5232	3008	Do. ...	Do........	[illegible]	[illegible]	107	[illegible]	[illegible]				[illegible]	[illegible]	9	[illegible] / 111	J. Walker
February 3rd ..	La Plata	....	[illegible]	[illegible]	1141	66½	10¾	[illegible]	[illegible]	Foul	Do.	[illegible]	[illegible]		77	[illegible]	[illegible]	[illegible]		[illegible] / 107	[illegible]	[illegible]	[illegible]	A. M[illegible]
February 17th	Tasmanian		[illegible]	[illegible]	[illegible]	[illegible]	11¾	3719	5450	Do.	Do.	[illegible]	[illegible]	21	[illegible]	7	[illegible]	72	[illegible]	12 / 117	[illegible]	15	[illegible] / 77	A. Wyle
March 2nd	Atrato		[illegible]	[illegible]	[illegible]	70	10¾	[illegible]	[illegible]	Clean	Do.	[illegible]	115	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	D. Brown
March 17th	Shannon		[illegible]	[illegible]	[illegible]	[illegible]	10½	5072	5191	Do. ..	Do.	112	[illegible]	117	[illegible]	[illegible]	6	18		[illegible] / 107	[illegible]	[illegible]	[illegible] / 112	J. Walker
April 2nd	La Plata		[illegible]	[illegible]	[illegible]	[illegible]	10¾	4075	5050	Foul	Do.	[illegible]	[illegible]	11	46	[illegible]	[illegible]	110		[illegible] / 104	[illegible]	[illegible]	[illegible]	A. M[illegible]
April 17th	Tasmanian		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6405	Clean	Do.	[illegible]	[illegible]	[illegible]	[illegible] / 18	[illegible] / 45	[illegible]	[illegible]	[illegible]	11 / [illegible]	[illegible]	[illegible]	[illegible]	A. Wyle
May 2nd	Atrato		[illegible]	[illegible]	[illegible]	70½	11¾	[illegible]	5008	Ordinary	Do.	51	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible] / 117	D. Brown
May 18th	Shannon		[illegible]	[illegible]	1103	67¾	10½	[illegible]	4971	Clean	Do......	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible] / 107	[illegible] / 12	[illegible]	J. Walker
June 2nd	La Plata		[illegible]	337	[illegible]	[illegible]	[illegible]	4046	5047	[illegible]	Mixed good	38	131	21	18	18	18	[illegible]		[illegible]	[illegible] / 178	21	[illegible]	A. M[illegible]

TABLE I.—ROYAL (WEST INDIA) MAIL PACKET COMPANY.—ST. THOMAS [illegible] SOUTHAMPTON. DISTANCE 3[illegible] MILES.

Date of [illegible]	Name of [illegible]	Tonnage, Builders' Measurement.	[illegible] of voyage	Time of passage in Hours, deducting [illegible]	Coal [illegible]	Mean consumption per Hour in lbs.	[illegible]	Mean [illegible]	Coal [illegible]	Condition of H[illegible] whether clean, ordinary, or foul.	Description and Quality of Coal, whether good, ordinary, or bad.	Hours Sail Set: Square	Hours Sail Set: F. & A.	No. of Hours at each Grade of Expansion: [illegible]	1st Grade	2nd Grade	[illegible]	4th Grade	5th Grade	Consumption of Stores: Oil in Gallons	[illegible]	[illegible]	[illegible]	[illegible]
18[illegible] July 30[illegible]	Atrato	....	44	314	1091	70	11¼	·070	51·6	Ordinary	Mixed, medium quality	60	138	.	9	220		...	..	17 / 67	[illegible]	[illegible]	[illegible]	D. [illegible]
August 1[illegible]	Shannon*	....	15	35[illegible]	1140	61½	10	1884	1635	Clean	Scotch, good	115½	173½	6	..	...		...	...	13¼ / 106¼	1 / 140	1 / 2	127 / [illegible]	J. Wilson
August [illegible]	Seine	....	13	341	1214	70½	10½	1975	1768	Foul	Good	2	118	6	327	14	..	..	.	18½ / 102	82 / [illegible]	11 / 1	[illegible]	[illegible]
September 1[illegible]	Tasmanian	...	13	333	1101	66¼	1[illegible]	·0747	15·1	Ordinary	Mixed, dirty, indifferent	128½	107	·75 / 100	·1 / 81	·40 / 30	·48 / 28		.	11 / 143	[illegible]	111	11	A. W[illegible]
September 2[illegible]	Atrato	....	45	320	1101	70½	11	·0865	1634	Foul	Indifferent	76	184	.	12	111	150		.	10 / 77	[illegible]	20	15[illegible] / [illegible]	D. Brown
October 13th	La Plata	....	53	357	1271	71	10½	1081	37·1	Ordinary	Mixed, light, & dirty	65	111		70	72	52	108	..	23 / 123	71 / [illegible]	20	[illegible]	A. M[illegible]
October [illegible]	Seine	....	14	357	1251	67½	10½	1876	11[illegible]	Clean	Quick burning, inferior	89	104	.	108	144	24	..	..	17 / 94½	[illegible] / 188	1 / 3	[illegible] / 17[illegible]	[illegible]
November 1[illegible]	Tasmanian	....	14	350	1007	61¼	1[illegible]	·076	10[illegible]	Do.	Mixed, ordinary	88	109		·20 / 20	·83 / 8	·36 / 333	..	.	16 / 130	[illegible] / 188	1[illegible]	[illegible] / 18[illegible]	A. W[illegible]
November [illegible]	Atrato	....	40	324	1103	73½	11	·087	10[illegible]	Do.	Good	95	98	10	132	96	60	..	.	7 / 76	[illegible]	[illegible]	[illegible]	D. [illegible]
December 1[illegible]	Shannon	....	10	337	1203	71½	1[illegible]	·0462	5·01	Do.	Mixed, good	74	133	163	178	...	...	...	...	14 / 123	[illegible] / 109	11	[illegible] / 11[illegible]	J. Wilson
December 31st	Seine	....	15	334	1118	69½	10	6000	5470	Ordinary	Good	108	216	..	390	..	...	.	...	15 / 93	20 / 118	18 / 1	212 / 178	J. Gold[illegible]
18[illegible] January 1[illegible]	Tasmanian	....	15	385	1070	60	.	·1701	35·0	Do.	Do.	132	199	·33 / 24	·30 / 12	·38 / 60	·4 / 12	·45 / 119	·48 / 48	11 / 128	[illegible] / 217	10	[illegible] / 10[illegible]	A. W[illegible]
January 3[illegible]	Atrato	....	47	329	1201	73½	11	1017	1588	Do.	Do.	14	93	10	120	155	12	...	...	7 / 73	27 / 109	1 / 0	147 / 110	D. Brown
February 15th	Shannon	....	17	326	1175	72	11½	1902	[illegible]	Do.	Mixed, dirty	157	227	144	186	...		..	...	11 / 102	65 / 1[illegible]	12	1[illegible] / 88	J. Wilson
March 2nd	La Plata	....	54	338	1240	73½	10½	[illegible]	1211	Foul	Mixed, fair, but dirty	104	103	12	36	84	204	...	.	20 / 109	57 / 1[illegible]	[illegible]	11[illegible] / 17[illegible]	A. Mentiplay
March 16th	Tasmanian	....	16	336	1072	63½	10½	·0771	·0712	Do.	Mixed, good, but dirty	77	206	·45 / 24	·48 / 12	·5 / 150	·55 / 10	·6 / 128	...	11 / 110	25 / 171	11	[illegible]	A. Wyle
March 29th	Atrato	....	48	320	1166	72½	11½	1116	·920	Clean	Ordinary	101	144	68	106	84	68	..	..	11 / 71	[illegible]	20	132 / 132	D. Brown
April 14th	Shannon	....	18	317	1176	76½	11½	5000	5·085	Do.	Mixed, ordinary	62	105	114	200	..	...	...	...	13 / 101	51 / 1[illegible]	12 / 13	11[illegible] / 1[illegible]	J. Wilson
April 29th	La Plata	....	55	322	1100	68½	11½	1112	[illegible]	Foul	Do.	53	103	18	48	48	213	...	..	20 / 110	34 / 134	31	1[illegible] / 165	A. Mentiplay
May 15th	Tasmanian	....	17	323	1007	66	11	·0[illegible]	[illegible]	Clean	Mixed, good	85	180	·5 / 60	·52 / 196	·55 / 48	·6 / 24	·64 / 32	.	5 / 107	20 / 197	11	68 / 97	A. Wyle
May 29th	Atrato	....	40	310	1256	76	11	[illegible]	1131	Ordinary	Fair	40	138	174	160	...	...	...	..	8 / 72	24 / 97	20	120 / 120	D. Brown
June 11th	Shannon	....	19	322	1112	71	11½	5271	6073	Clean	Mixed, good	95	121	115	212	...	...	..	..	11 / 166	40 / 119	23	139 / 106	J. Wilson
June 30th	La Plata	....	56	320	1170	71	11	·077	1705	Foul	Do.	63	121	18	48	48	96	123	...	10 / 102	32 / 180	54	1[illegible] / 180	A. Mentiplay

* Steamed home at reduced pressure; cross tail port engine cracked.

Note.—The *Tasmanian* is the only screw steamer in the Tables. In the case of *Tasmanian's* grades of expansion, the upper figures are the decimal portions of stroke at which steam is cut off, and the lower ones the number of hours at those grades. The upper line of figures under the head of consumption of stores, shows the expenditure of stores in harbour.

TABLE II.—PARTICULARS OF 12 STEAMSHIPS INDICATED BY LETTERS OF REFERENCE.

Letter of Reference.	A	B	C	D	E	F	G	H	I	J	K
Date of build	1856	1855	1855	1851	1851	1853	1855	1857	1855	1851	1855
Built of	iron	iron	iron	iron	iron	iron	iron	iron	[illegible]	iron	[illegible]
Propelled by	screw	screw	screw	screw	screw	screw	screw	screw	screw	screw	screw
Length	325·4	310	300·5	261·8	212·3	257·4	277	250	233·9	188	[illegible]
Breadth	39·1	40·1	39·6	36·2	30·0	36·3	36·3	31	[illegible]	[illegible]	[illegible]
Depth of hold	25·8	19·2	19·0	23·3	18·0	19·0	23·3	22	[illegible]	17·0	[illegible]
Tonnage gross	2303	2381	2107	2066	1007	1710	1954	1457	1000	718	671
Nominal horse-power	500	400	450	450	400	300	400	200	134	160	[illegible]
Number of cylinders	2	2	2	2	2	2	2	2	2	2	2
Diameter in inches	83	76	76	71	71	63	64	50	52	47½	50
Stroke of piston in inches	72	72	72	60	60	60	32	36	36	34½	36
Revolution of propeller for one of engine	3·05	2·88	2·88	2·21	2·21	2·05	1	1	1	1	1
Air-pump diameter	41in.	41½in.	45in.	31in.	31in.	28½in.	16in.	40in.	29in.	27in.	[illegible]
Air-pump stroke	26in.	29½in.	29½in.	21in.	24in.	30in.	32in.	9in.	[illegible]	17½	[illegible]
Number of air-pumps	2	2	2	2	2	2	4	1	2	2	2
Displacement of piston / Displacement of air-pump	10·2	13·8	13·28	26·23	27·4	11·0	11·0	14	12·6	11·0	9·0
Vacuum maintained*	..										
Feed-pump diameter	5¼	7¾	7¾	6		4¼	6¼	8¼	5¼	6¼	8
Feed-pump stroke	26	29½	29½	25½	..	14	32	6	11	17	8
Feed-pumps, number of	4	4	4	2		2	3	1	..	1	2
Displacement of piston / Displacement of air-pump	308	26	240	320	...	175	148	110	150	171	160
Main steam pipe diameter	22in.	22½in.	21¼in.	17½in.	18¼	11in.	20	13½	11	[illegible]	12
= D √n ×	·19	·212	·200	·177	·182	·156	·223	·17	·155	·161	·177
Exhaust from each cylinder	20¼ × 10	17¼ × 10	17¼ × 10	15¼ × 11¼	16¼ × 11¼	13	17¾	12	11	[illegible]	11
Diameter of exhaust = D ×	·197	·198	·198	·197	·210	·206	·277	·215	[illegible]	[illegible]	[illegible]
Slide-valve travel	11½	11	11½	9¼	9	10	6½	8½	8	[illegible]	[illegible]
Steam cap	4	2½	3½	2½	3½	2¼	1¾	[illegible]		[illegible]	[illegible]
Length of steam port = D ×	·38	·47	·47	·30	4·0	·30	·04	[illegible]	·12	[illegible]	·11
Width of ditto = D ×	·06	·065	·067	·062	·063	·058	·043	·071	·078	[illegible]	·077
Area of piston ÷ area of port =	20·3	25·2	24·5	31·6	30·8	21·8	28	19·8	21·5	22·7	[illegible]
Port area = D² ×	·0266	·031	·032	·0253	·025	·036	·027	·030	·033	[illegible]	[illegible]
Steam cut off at	·43	·09	·04	·64	·305	·71	·83	·03	[illegible]	7	[illegible]
Diameter of propeller	17½ft.	16ft.	16ft.	14ft. 3in.	14ft. 3in.	12ft. 3in.	17ft.	15ft. 6in.	[illegible]	110	110
Pitch of ditto	16ft.	20ft.	22ft.	18ft.	18ft.	15ft.	24ft.	21ft.	[illegible]	[illegible]	[illegible]
Total firegrate, square feet	308	260	270	118	174	210	204	144	174	[illegible]	111
= n D² ×	43·0	44·4	42·7	68·1	72·2	38·8	27·6	44	41	17·7	41
Total tube surface inside	6600	5300	4340	3300	3800	4300	4180	3107	3449	[illegible]	2980
= n D² ×	3·07	2·22	2·03	3·05	2·65	1·80	1·97	1·82	[illegible]	[illegible]	1·67
= Firegrate ×	21	20	18·2	22·1	28·2	20	13·6	21·3	[illegible]	[illegible]	20·4
Pressure in boilers	12	10	12	11	15	11	15	15	15	[illegible]	14
Revolutions of engines per minute	23	17¾	17	24	27	[illegible]	14	12	17	[illegible]	12
Revolution of propeller per minute	67½	51½	49	53	[illegible]	[illegible]	[illegible]	12	47	[illegible]	[illegible]
Velocity of piston, feet per minute	264	213	204	240	[illegible]	310	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Velocity of propeller, knots per hour	10·8	10·2	10·8	9·64	[illegible]	12·1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Velocity of vessel, knots per hour	11·5	11·	10·5	9·0	9·5	10·0	11·0	11·0	12·1	9·8	11
Indicated horse-power	1000	830	1010	...	810	[illegible]	[illegible]	[illegible]	9·0	9·0	[illegible]
Coals per ton per hour	4·01	4·08	4·15	...	3·92	[illegible]	[illegible]	3·71			[illegible]
Coals per foot of firegrate per hour	13·0	15·1	15·5	15·0	11·4	16·4	[illegible]	11·4	11·8	12·7	11·[illegible]

* Not given, but it varies from 22in. to 26in.

TABLE III.

ROYAL (WEST INDIA) MAIL PACKET COMPANY.

SUMMARY MADE FROM THE TABLES OF DIAGRAMS FROM INDICATOR, AND WORKING OF THE ENGINES BELONGING TO THE VARIOUS SHIPS INCLUDED IN THE RETURN FURNISHED OF THE PERFORMANCES FROM ST. THOMAS TO SOUTHAMPTON BETWEEN JULY 30, 1863, AND JUNE 30, 1864, AS GIVEN IN TABLE I.

Date.	Name of Ship.	Nominal Horse-power.	Revolutions per Minute.	Pressure of Steam as per Gauge.	Vacuum as per Gauge.	Grade of Expansion.	Average Steam as per Card.	Average Vacuum as per Card.	Indicated Horse-power—two sides of one cylinder.	Total Indicator Power calculated from one cylinder.	Area of Cylinder, in square inches.	Length of Stroke	Coals consumed per hour.	Coals consumed per H.P. nominal per hour.	Coals consumed per Indicator H.P. per hour.	Coals consumed per mile.	Speed in knots per hour.	Slip per Cent. of Wheels or Screw.	Remarks.
				lbs.	In.		lbs.	lbs.				ft. in.	cwt. qrs. lbs.	lbs.	lbs.	lbs.			
Voyage 44th	Atrato	76	14·25	14	26	1st & 2nd	7·080	11·45	1018·72	2007·44	7313·8	0 0	68 2 21	10·04	3·07	5·05	11·5	17·85	Wind on bow, and occasional calm.
" 15th	Shannon	774	12·65	10	28	F. S. ½ throttle	4·897	12·046	891·67	1763·34	7369·8	0 0	62 2 14	9·04	3·05	0·36	9·64	·21	Wind and sea before beam, blowing hard, swell, rolling.
" 13th	Seine	800	14·35	18	25½	1st	6·212	11·382	1256·75	2513·5	7389·8	10 0	69 3 25	9·79	3·11	6·25	10·89	23·4	Bow wind, fine.
" 13th	Tasmanian	714	39·5	15	20	18in. & 21in.	3·096	9·28	404·33	1912·00	3029	3 6	57 0 0	8·575	5·255	5·466	10·456	18·2	Light head winds, and calm.
" 45th	Atrato	766	14·75	14	26	1st, 2nd, & 3rd	5·025	10·655	917·125	1834·2[illegible]	7313·8	0 0	60 0 0	[illegible]	[illegible]	6·215	11·08	20·7	Light beam and quarterly winds; sails set
" 23rd	La Plata	873	11·4	14¼	27	1st & 4th	[illegible]	10·835	894·87	1787·74	8332·3	0 0	60 1 0	8·91	4·572	6·7	10·135	12·0	Head and variable winds; heavy sea.
" 14th	Seine	800	14·4	18	29	2nd & 1st	7·892	11·112	1245·75	2491·5	7389·8	10 0	73 2 27	10·3[illegible]	3·415	6·25	11·72	20·35	Beam and quarterly wind; heavy sea; sails set
" 14th	Tasmanian	714	40·4	15	27½	23in. & 1[illegible]in.	3·510	9·018	392·2	1170·6	3029	3 0	55 3 0	8·85	5·323	6·235	10·75	17·56	Light head winds, occasional fair wind; sails set
" 46th	Atrato	766	14·0	14	26	1st & 2nd	6·020	11·201	1074·33	2148·66	7313·8	0 0	73 2 0	10·74	3·827	6·4	11·35	21·6	Light head and quarterly wind; sails set
" 30th	Shannon	774	14·35	17·27	27·35	F. S. & 1st	9·177	12·036	1270·67	2541·34	7369·8	0 0	70 1 14	10·16	3·109	6·0	11·59	17·8	Shifting wind; swell, and fine weather
" 15th	Seine	800	16·05	18	20	1st	8·378	11·502	1339·25	2078·50	7180·8	10 0	70 0 26	9·83	2·932	5·72	11·38	10·85	Beam and bow winds; fine
" 15th	Tasmanian	714	43·6	15	26½	21in. & 27in.	5·134	10·017	5[illegible]3·21	1327·03	3029	3 0	61 3 0	9·735	4·79	6·3	10·79	21·6	Strong head and light fair winds.
" 47th	Atrato	766	14·15	14	26	1st & 2nd	7·157	11·135	1041·91	2131·[illegible]	7313·8	0 0	71 2 0	10·45	2·817	6·05	10·725	22·125	Wind on starboard and head.
" 17th	Shannon	774	14·55	17	27¼	F. S. & 1st	10·316	12·54	1338·62	2077·24	7369·8	0 0	70 2 0	10·10	2·952	6·7	9·955	10·75	Quarterly wind.
" 54th	La Plata	873	12·55	14	27	2nd & 3rd	7·431	10·9[illegible]	101[illegible]	2[illegible]8·21	8332·3	0 0	72 2 0	9·3[illegible]	3·867	6·15	10·[illegible]	19·5	Fair wind; high sea; sails set.
" 16th	Tasmanian	714	43·05	15	26	24in.	0·373	10·007	531·51	101[illegible]	3321	3 0	63 2 14	9·575	[illegible]	5·75	10·[illegible]	20·0	Head winds, smooth water.
" 48th	Atrato	766	14·15	14	23	1st & 2nd	6·722	11·277	1037·13	2071·27	7313·8	0 0	71 1 0	10·115	3·832	6·21	10·775	19·25	Wind on beam, and strong breeze on quarter; sea; sails set.
" 18th	Shannon	774	14·15	17·85	27¼	F. S. & 2nd	9·517	12·213	1237·1	2374·2	7369·3	0 0	63 2 10	8·21	2·012	5·7	11·115	20·25	Fine weather; plain sails set.
" 55th	La Plata	873	12·0	14	27	1st & 3rd	7·702	11·20	1083·03	2107·81	8332·3	0 0	60 0 0	6·85	3·53	6·05	11·315	11·65	Wind on beam; light airs and fine
" 17th	Tasmanian	714	42·05	15½	26	21in. & 27in.	6·324	10·18	535·21	1009·23	3629·0	3 0	63 3 0	9·5[illegible]3	4·108	5·80	10·725	20·3	Head and bow winds, and sea.
" 40th	Atrato	766	14·15	10½	20	F. S. & 2nd	5·400	11·07	910·12	1808·84	7313·8	0 0	71 1 0	10·415	3·025	6·0	11·935	17·1	Starboard and quarterly winds; sails set.
" 10th	Shannon	774	14·46	17¾	27·35	F. S. & 1st	10·051	12·086	1321·3	2642·6	7389·8	0 0	69 3 10	10·11	2·08	6·04	11·56	14·1	No wind; fine weather.
" 50th	La Plata	873	11·4	14	27	1st	9·075	10·675	1054·3	2106·6	8332·3	0 0	74 0 0	9·24	3·92	0·7	10·71	6·8	Bow wind, fore and aft sails set

TABLE 6.

ABSTRACT OF ENGINEER'S LOG OF T[illegible] EASTERN" SEVENTH VOYAGE FROM LIVERPOOL TO NEW YORK, [illegible]

[illegible]

TABLE 7.

ABSTRACT OF ENGINEER'S LOG OF THE "GREAT EASTERN" SEVENTH VOYAGE FROM NEW YORK TO LIVERPOOL, JUNE, 1862.

[illegible]

TABLE 8.

ABSTRACT OF ENGINEER'S LOG OF THE "GREAT EASTERN" EIGHTH VOYAGE FROM NEW YORK TO LIVERPOOL, JULY AND AUGUST, 1862.

[illegible]

TABLE 9.

[illegible]T OF ENG[illegible]R'S LOG OF THE "G[illegible]AT EASTERN" [illegible]TH VOYAGE FROM NEW YORK TO LIVERPOOL, [illegible]

[illegible]

TABLE 10.—ABSTRACT OF THE ENGINEER'S LOG OF THE STEAMSHIP "GREAT EASTERN," EIGHTEEN VOYAGES, 1860-1863.

Name of Port	Date of Departure	Date of Arrival	Immersion on Departure For. ft. in.	Immersion on Departure Aft. ft. in.	Mean Immersion on Departure ft. in.	Immersion on Arrival For. ft. in.	Immersion on Arrival Aft. ft. in.	Mean Immersion on Arrival ft. in.	Time between Ports Days hrs.	Paddle Engines. Total Revolutions	Revolutions per Minute	Steam Gauge lbs.	Fuel used per Hour Tons.	Knots run by the Paddles Knots.	Slip per cent. of Paddles	Screw Engines. Total Revolutions	Revolutions per Minute	Steam Gauge lbs.	Knots run by the Screw Knots.	Slip per cent. of Screw	Fuel used per Hour Tons.	Total Fuel Expended Tons.	Knots run by Ship Knots.	Average Knots per Hour Knots.	Knots per Hour per Ton of Coal Knots.
Southampton to New York	June 17, 1860	June 28, 1860	21 8	26 1	23 7½	...	...	...	11 1	164,320	10	19½	110	3,061	19	533,024	34·7	17½	3,001	17·7	163	2,877	3,311	13	805
New York to Milford	[illegible]	Aug. 27, 1860	...	...	...	...	...	...	9 4	146,226	10·9	22½	122	3,765	18·8	508,194	35·8	19	3,670	16·5	193	2,744	3,064	13·5	[illegible]
Milford to New York	[illegible]	May 12, 1861	23 0	26 4	25 0½	19 6	25 0	22 3	9 18	133,000	9·48	21½	114	3,177	15	525,270	37·5	17½	3,712	21	158	2,717	3,017	13·75	[illegible]
New York to Liverpool	[illegible]	June 4, 1861	22 0	25 5	24 1	19 4	24 0½	21 9	9 3	137,430	10·4	21½	113	3,456	12·5	520,407	38·5	18½	3,016	18·7	178	2,803	3,083	14	
Liverpool to Quebec	[illegible]	July 7, 1861	23 4	28 1	25 8½	21 6	25 6	23 6	8 23	131,219	10·3	22	143	3,260	16	472,310	30·7	19	3,409	22·5	182	2,931	2,807	13·33	1·04
Quebec to Liverpool	[illegible]	Aug. 16, 1861	24 6	26 6	25 6	21 0	23 0	22 0	8 22	135,910	10·57	21	172	3,359	14·6	480,898	37·5	19	3,428	16·3	207	3,384	2,869	13·37	1·17
Milford to New York	[illegible]	May 17, 1862	20 8	26 8	24 11½	19 6	25 0	22 3	9 18	117,850	10·5	21½	119	3,564	12·6	511,976	30	18	3,690	29·3	152	2,715	3,070	13·5	[illegible]
New York to Liverpool	June 1, 1862	June 11, 1862	25 0	25 0	25 3	21 0	23 0	22 0	9 11	149,310	11	20½	137	3,883	16·5	515,570	37·4	16½	3,832	15·4	170	2,904	3,142	[illegible]	[illegible]
Liverpool to New York	July 1, 1862	July 12, 1862	23 6	26 0	24 9	20 9	25 4	23 1½	9 11	153,180	11·25	21½	139	3,783	19	508,230	37·3	16½	3,670	16·0	168	2,926	3,059	13·18	[illegible]
New York to Liverpool	July 27, 1862	Aug. 6, 1862	20 8	29 9	28 0	24 6	25 6	25 0	10 0	179,228	9·7	21½	139	3,478	10·8	494,185	35	17½	3,663	11·05	165	3,051	3,128	13·04	[illegible]
Liverpool to New York	Aug. 17, 1862	Aug. 27, 1862	20 0	20 0	20 0	22 0	25 0	23 6	10 14	160,815	10	21	140	3,736	17·04	521,716	34·5	17	3,755	14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York to Liverpool	Jan. [illegible] 1863	Jan. 17, 1863	25 2	29 11	27 6½	21 3	28 6	24 10½	11 3	118,158	9·3	20	137	3,695	16·7	621,910	32·6	17½	3,759	[illegible]	[illegible]	[illegible]	[illegible]	11	1·17
Liverpool to New York	May [illegible] 1863	May 29, 1863	23 11	26 2	25 0½	21 10	23 8	22 9	11 1	119,038	9·35	21	126	3,704	16·25	564,900	35·5	17½	4,021	[illegible]	[illegible]	[illegible]	[illegible]	11·7	[illegible]
New York to Liverpool	[illegible] 7, 1863	June 18, 1863	27 0	28 1	27 6½	23 6	25 10	24 8	10 0	141,711	9·4	21	122	3,964	8·02	631,170	35·3	17½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Liverpool to New York	[illegible]	July 12, 1863	23 0	27 6	25 7½	21 2	25 0	23 1	11 16	162,001	10·2	21	111	3,898	25	[illegible]	[illegible]	17	[illegible]	[illegible]	175	[illegible]	[illegible]	[illegible]	[illegible]
New York to Liverpool	July [illegible] 1863	Aug. 2, 1863	25 9	28 0	26 10½	23 0	25 0	24 4½	10 23	139,175	9·23	21	111	3,499	13·8	627,540	33·75	16	3,801	[illegible]	173	[illegible]	[illegible]	[illegible]	[illegible]
Liverpool to New York	Aug. 12, 1863	Aug. 25, 1863	23 9	26 1	24 11	20 4	25 6	23 0	11 21	153,556	9	18	105	3,856	18·41	673,900	33·67	16½	4,180	[illegible]	170	[illegible]	[illegible]	[illegible]	[illegible]
New York to Liverpool	Sept. 8, 1863	Sept. 20, 1863	27 3	28 1	27 8	23 0	26 0	24 9	11 3	119,419	9·32	20½	168	3,615	12·8	511,270	32	17	3,727	10·28	167	3,207	3,304	11·70	1·04
Total [illegible]									184 0	2,631,501	...	...	...	65,257	...	9,377,363	...	...	67,595	...	...	55,171	55,270		...
Average [illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23 3½	10 5½	146,190	9·94	...	...	3,628	15·34	520,965	35·32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE II

RETURNS OF H.M.S. STEAM LINE OF BATTLE SHIP "VICTOR EMANUEL"

Date	State of Sea	Sails set	Area	Engines: Cut-off in proportion	Coals: Description	Efficiency			Remarks
			sq. ft.						
13th February, 1860	[illegible]	Single reefed topsails, courses [illegible] and jib [illegible]	2731						Leaving Gibraltar
14th February, 1860	[illegible]	Single reefed topsails, courses [illegible] foretop staysail, jib and spanker.	[illegible]						Gibraltar to Malta
17th February, 1860	[illegible]	Single reefed topsails [illegible] staysails occasionally	3030						Gibraltar to Malta
20th February, 1860	[illegible]	Double reefed topsails and [illegible]	[illegible]						
21st February, 1860	[illegible]	Treble reefed fore and main [illegible] topsail and foresail.	[illegible]						
17th April, 1860	[illegible]	All plain sail except royals and flying jib.	3384						Left Malta for Corfu
18th April, 1860	[illegible]	Double reefed topsails, courses, top gallantsails, jib, fore [illegible]	3030						Malta to Corfu.
[illegible]	Heavy sea on from S.E.	Single reefed topsails, courses [illegible] jib, fore [illegible]	3155						Corfu to Malta.
[illegible]	[illegible]	[illegible]	[illegible]						Malta to Gibraltar, ship's bottom very foul
[illegible]	[illegible]	[illegible]	[illegible]						Malta to Gibraltar, ship's bottom very foul
[illegible]	[illegible]	Ditto							
[illegible]	[illegible]			[illegible]	Welsh mixed.	503	141	5·84	Corfu to Malta.
[illegible]	[illegible]			Expansion [illegible], and links raised 1in	Welsh mixed	533	151	6·16	Malta to Gibraltar, ship's bottom very foul
[illegible]	[illegible]			Expansion [illegible]	[illegible]	403	113	5·47	Malta to Gibraltar, ship's bottom very foul
[illegible]	[illegible]			[illegible] links raised 4in	[illegible]	450	126	[illegible]	
[illegible]	[illegible]			Expansively	[illegible]			[illegible]	
23rd March, 1862	[illegible]			[illegible] 168, and [illegible]		216	61	[illegible]	Ship pitching heavily, coals very bad.
24th March, 1862	Heavy swell from S.W.			Ditto				[illegible]	Ship pitching heavily, coals very bad.
25th March, 1862	[illegible]			Expansion 3/7, and links raised 5in		250	67·5	[illegible]	
1st April, 1862	[illegible]			expansively					
2nd April, 1862	[illegible]			[illegible]					
3rd April, 1862	Steaming through Gibraltar Straits			[illegible]	[illegible], very good	[illegible]	79·6	[illegible]	Gibraltar to England
4th April, 1862	Steaming through Gibraltar Straits			[illegible]	[illegible], very good.	[illegible]	140	3·62	Gibraltar to England
25th March, 1862	[illegible]	Plain sail to single reefed tops[ails]	[illegible]	Expansion [illegible], and links [illegible]	Welsh mixed.	676	240	5·31	Malta to Gibraltar, ship's bottom very foul.
1st April, 1862	[illegible]	[illegible]	[illegible]	Expansion [illegible] links raised [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Malta to Gibraltar, ship's bottom very foul
2nd April, 1862	[illegible]	[illegible]	[illegible]	Expansion [illegible] links raised [illegible]	Aberdare.	638	176	4·47	Gibraltar to England
6th April, 1862	[illegible]	All sail to fore [illegible] and fore studding	3010	Expansion 1/10, and links not raised.	[illegible]	909	227	6·42	Gibraltar to England

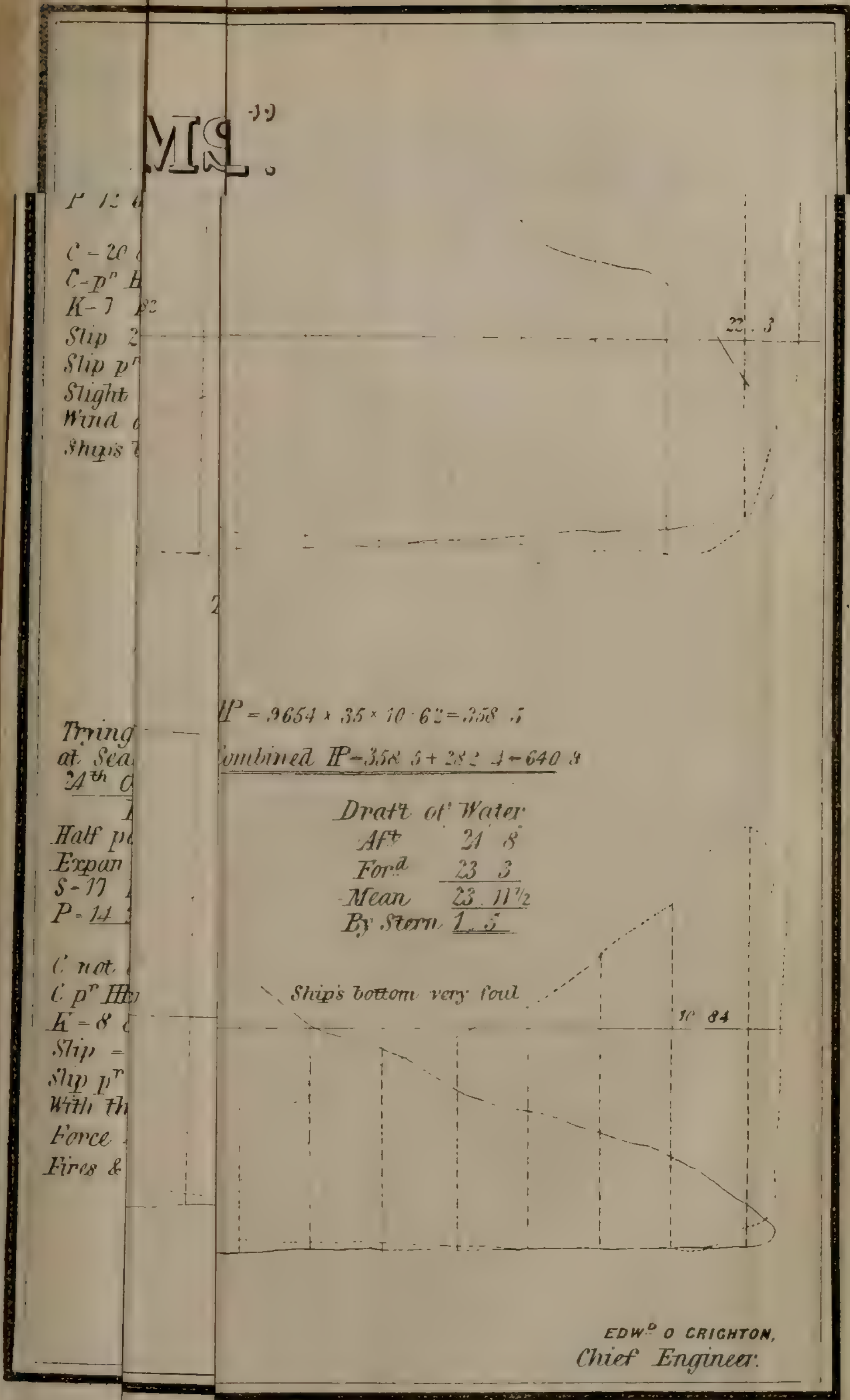
[illegible] would only lead to mislead.

RÉSULTATS DE LA NAVIGATION DES PAQUEBOTS DES SERVICES MARITIMES DES MESSAGERIES IMPÉRIALES PENDANT L'ANNÉE 1861

	Total du Parcours	Heures de Chauffe	Heures de Marche	Vapeur	Ouverture des Registres de Vapeur	Différence de Temps d'Eau	Consommation de Charbon: Totale	Moyenne par Heure	Par Lieue marine et par Heure	Chemin	Consommation
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAUX	[illegible]	2 204 [illegible]	[illegible]	...			[illegible]	[illegible]	17,7[illegible]	210 [illegible]	[illegible]
MOYENNES	[illegible]	2 054 18	2 333 31	...			7 030 31	[illegible] 301	4 0 — 6 0	6,675 — 0·168 — 0 57	311 — 1 774

SERVICES MARITIMES DES MESSAGERIES IMPÉRIALES NAVIGATION DES PAQUEBOTS PENDANT L'ANNÉE 1862

Paquebots	[illegible]	Nombre de Tours pendant [illegible]	Nombre de Tours [illegible] après la Coup	Force Nominale [illegible] correspondante [illegible]	Total du Parcours	Heures de Chauffe	Heures de Marche	Tension Moyenne de la Vapeur	Vide Moyen du Condenseur	Ouverture des Registres Vapeur	Introduction moyenne Vapeur dans les Cylindres	Consommation de Charbon: Totale	Moyenne par Heure	Par Lieue marine	Par Cheval Nominal et par Heure	Par Force de Cheval nominal réalisée, et par Heure	[illegible]: Totale	Par Cheval et par 24 Heures	Vitesse sur la Route directe
																Kilo. 4·1	Kilo. 0·391	Kilo. 0·157	Nœuds. 8·45
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Totaux	[illegible]				13,720	[illegible]	[illegible] 45	[illegible] 45				[illegible]	[illegible]				[illegible]	[illegible]	
Moyennes	203				[illegible]	7 476	[illegible] 50	[illegible]				[illegible]	1,34	250	1 2	4 7	64 4	0·102	[illegible]



MS.
Trying
at Sea
$IP = .9654 \times 35 \times 10 \cdot 62 = 358.5$
Combined $IP = 358.5 + 282.4 = 640.9$
Draft of Water
Aft 21 8
Ford 23 3
Mean 23 11½
By Stern 1 5
Ship's bottom very foul
22 . 3
10 84
EDWD O CRICHTON,
Chief Engineer.

INDICATOR DIAGRAMS OF H.M.S "VICTOR EMANUEL"

FORE CYLINDER

Trying rate of Steaming at Sea
Fore Cylinder
Half power 2 Boilers
not ascertained
K = 8 8
slip = 2 18 knots
slip p^r cent = 19 9
with the Wind
Force 4 to 5
Fires & Flues not very clean

$IP = 9654 \cdot 42$

Draft of Water
Aft
For^d
Mean
By Stern

Ships bottom very foul

Full power Boilers
not ascertained
per Indic H^r not ...
K = 9 7
slip = 3 82 knots
slip p^r cent = 25
Moderate swell
Force 4 to 5
Against the Wind
Fires & Flues not very clean

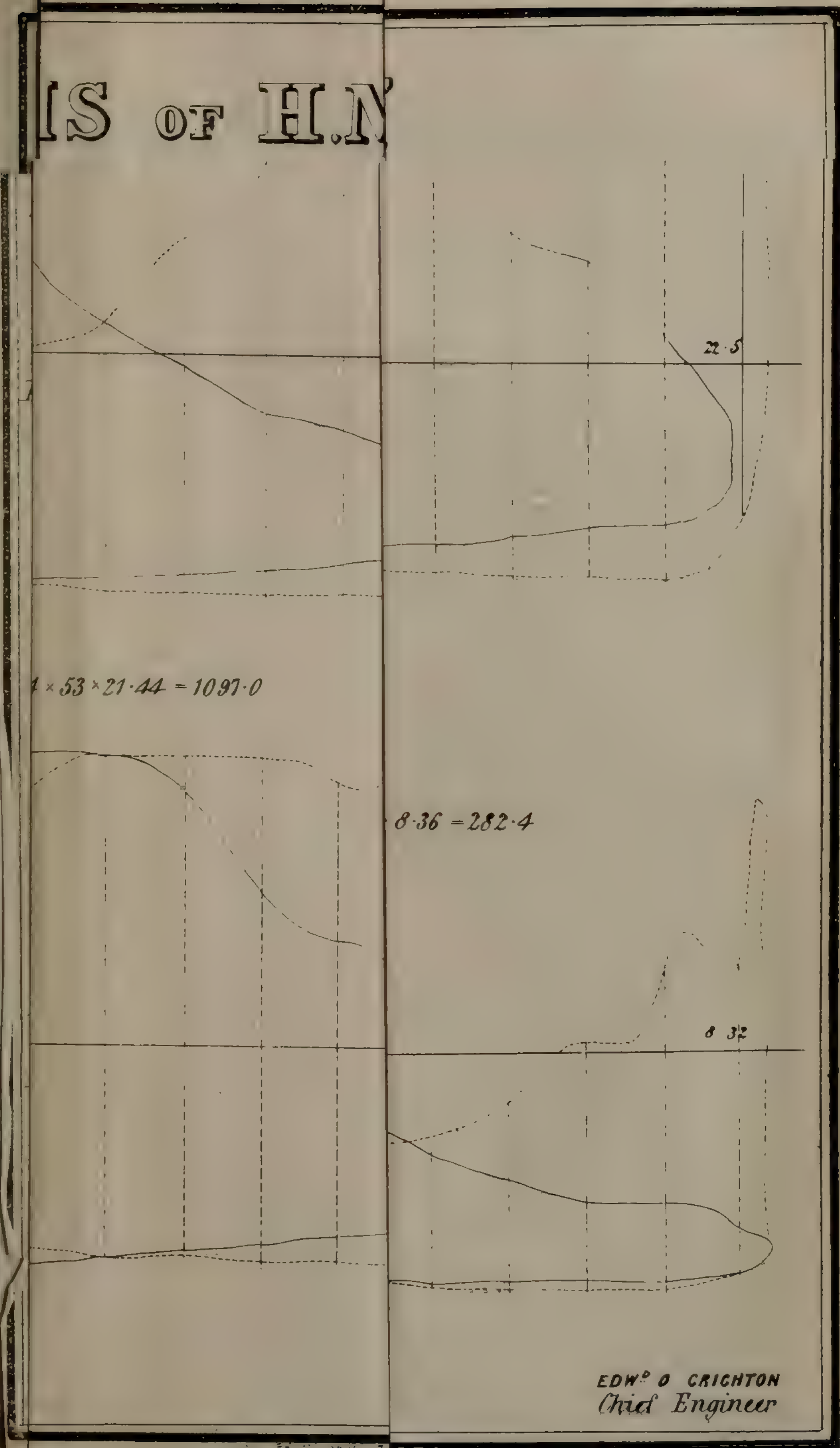
Ships bottom very foul

Fore Cylinder
slip per cent
Wind
Force
Fore & Aft Sails set. Mod swell

Draft of Water
Aft
For^d
Mean
By Stern

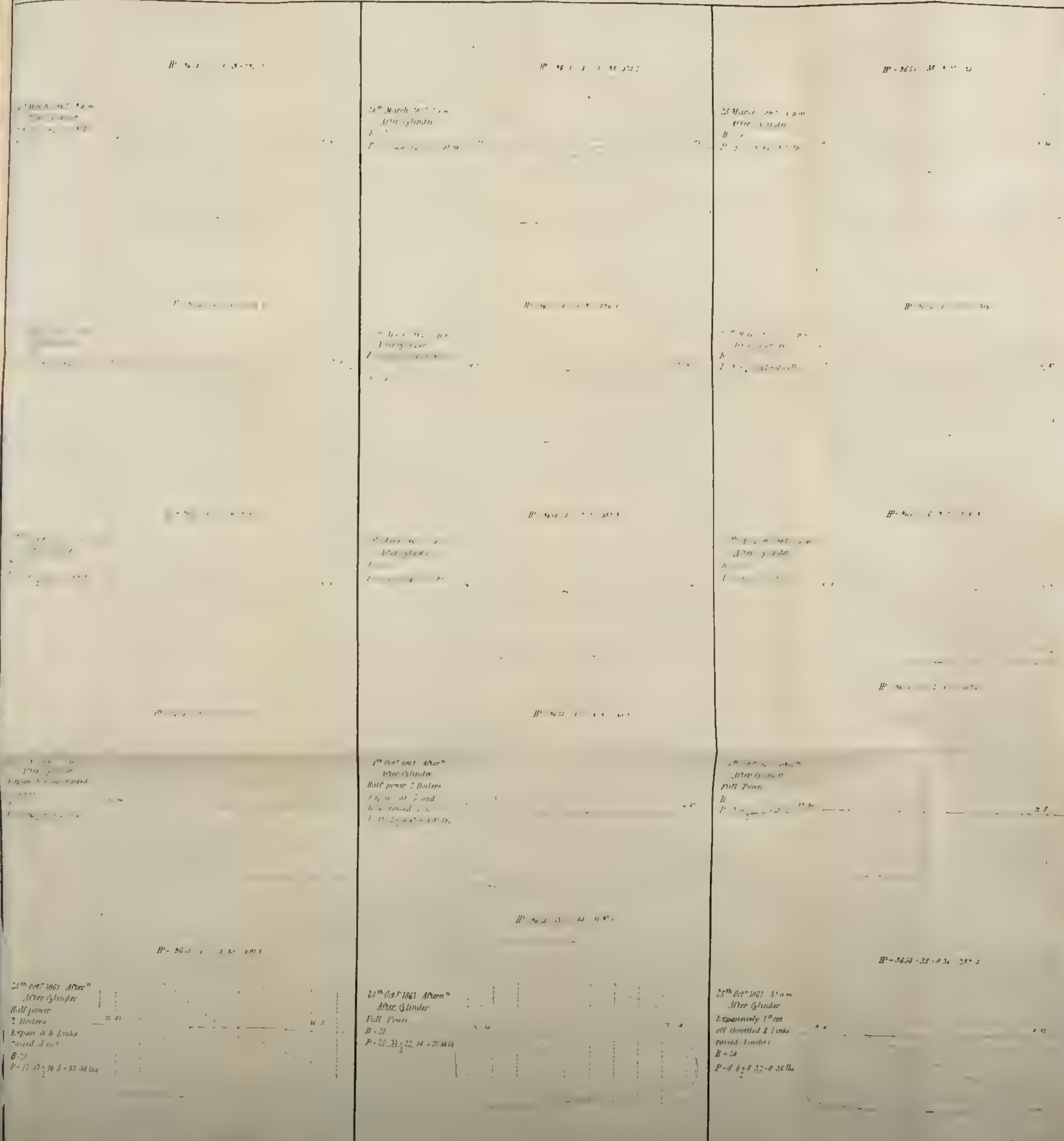
Chief Engineer

PLATE VIII


IS OF H.N
22·5
× 53 × 21·44 = 1097·0
8·36 = 282·4
8 32
EDWD O CRICHTON
Chief Engineer

INDICATOR DIAGRAMS OF H.M.S "VICTOR EMANUEL."

AFT CYLINDER)



To accomplish what had been proposed, and fully to realize the expectations of the public, was naturally a subject of no small anxiety to those on whom the responsibility devolved of providing vessels so much in advance of any which had yet been built. It was not a mere question of speed at the measured mile in Long Reach or in Stokes Bay; that had been shown to be practicable by the great success of the Royal Yacht, which attained the unprecedented rate of speed, at the trial trip, of $19\frac{1}{3}$ statute miles per hour (*vide* Table); the difficulty was to maintain such a rate of speed in severe weather, and under the disadvantageous circumstances which must so often occur in the passage of the Channel four times every day in the year, as to insure comparative regularity in the due performance of a mail service, with but very small margin for contingencies at sea. With the object therefore of insuring this result, it was ultimately decided to increase the size of the vessels to 2000 tons, and that of the engines in like proportion. Designs were received from the most eminent builders in England. Those submitted by Messrs. Laird, of Birkenhead, and Mr. Samuda, of London, were adopted. Messrs. Ravenhill, Salkeld, and Co. supplied two pairs of engines, and Messrs. James Watt and Co. the other two pairs. The dimensions and general arrangements of the four vessels are so nearly alike, that the following description of one, the 'Connaught,' will be sufficient for all. This was built by Messrs. Laird, as well as the 'Ulster' and the 'Munster;' the fourth, the 'Leinster,' was built by Mr. Samuda.

The ships are built of iron. The length between the perpendiculars is 334 ft.; the beam is 35 ft., and depth 21 ft. The keel is formed of a centre keel plate, 3 ft. deep and $\frac{5}{8}$ in. thick, with two bars 9 in. deep by $\frac{5}{8}$ in. thick, on each side at the bottom; these five plates, with the two garboard strakes, $\frac{7}{8}$ in. thick each, are secured together with iron bolts riveted and countersunk. On the top of the centre keel plate two angle-iron bars are riveted, 5 in. by 4 in. by $\frac{1}{2}$ in., and to these angle irons, and to the angle irons on the top of the floorings throughout the entire length of the vessel, as far as the fine ends will allow, is riveted a strong plate, 4 ft. wide amidships, and 2 ft. 6 in. wide at the ends. There are also two very strong box keelsons, secured on the floorings at each side of the keel, and another in each bilge. The general framing of the ship and the outside plating are done in the usual way, care being taken to have everything well put together. The engine beams, paddle and spring beams, and all other beams for the main and lower decks are of iron. Timber has been used only for the decks and cabin fittings. There are nine principal iron water-tight bulkheads, which not only provide for the safety of the ship in case of accident, but add greatly to her strength in a seaway. The bulwarks are of iron plates, in continuation of the sides of the vessel to the rail, and without any break for gangways, such not being required for landing, either at Holyhead or at Kingstown. To give additional strength in the centre, where the weight of the engines, wheels, and boilers has to be carried, the insides of the paddle-boxes are also formed of iron plates, continued from the sides and bulwarks of the vessel, with a strong bow girder, formed of an iron plate 15 in. broad and $\frac{3}{4}$ in. thick, so as to provide ample means of resistance to the severe shocks which these long vessels must encounter in rough seas, when driven at such a high rate of speed. The gunwale is formed of angle-iron bars, 4 in. by 4 in., riveted to the sheer strake and to a plate which is riveted on the top of the beams. At a distance of about 15 in. from this, an inner angle bar is riveted, against which the wooden waterway is fitted, so as to leave the outer part, between this and the gunwale, to form a drain to take the water off the deck, and to

discharge it through the scuppers. This arrangement, which was introduced by Mr. Laird, has been found very convenient, in freeing the decks quickly from water. These iron gunwale plates are 5 ft. wide by $\frac{3}{4}$ in. thick amidships, tapering gradually to about 2 ft. 6 in. by $\frac{1}{2}$ in. at the ends, with a system of diagonal tie plating from side to side, securely bolted or riveted to the deck beams. Between the paddle-boxes, an upper deck, about 50 ft. in length, has been placed. It is laid on iron beams well secured, and being provided also with diagonal tie plates, it further adds to the strength amidships; though the primary object was for the more rapid embarkation and landing of passengers and luggage at times of low water, both at Holyhead and at Kingstown. It also forms an agreeable promenade for the passengers in moderate weather. The wheel and the binnacle are placed on this upper deck, so as to allow of the commander and the officers being near to the men engaged in steering. All difficulty is thus avoided in passing the word, a distance of nearly 200 ft., as would have been necessary, in the ordinary way. The entire of the main deck, from the foremost funnel to the bows, is covered over by a hurricane deck formed with angle-iron beams, 5 in. by $2\frac{1}{2}$ in., extending from the rail at each side, and boarded over with planks $1\frac{1}{2}$ in. thick, leaving when at sea but one small opening round the foremast. This construction has been found of great advantage in throwing off the seas, which, previously to the vessels being thus protected, occasionally in heavy weather caused damage to the skylights and the upper works. The weight of so large a piece of work, about 140 ft. in length, is considerable, and increases the immersion of the vessel forward; but this has been amply compensated for by the security afforded when pressing at a high rate of speed in tempestuous weather. There has not been the slightest damage to any of the vessels, during the last two years, since they were completely provided with this excellent protection. The plan was copied from a small vessel, the 'Menai,' fitted out in Liverpool for the River Plate in 1854.

The engines for all the vessels are on the oscillating principle. In the two pairs made by Messrs. Ravenhill, Salkeld, and Co., for the 'Leinster' and the 'Connaught,' the cylinders are 98 in. diameter, with a length of stroke of 6 ft. 6 in.; the air-pumps are 54 in. diameter, with a stroke of 2 ft. 6 in. The eight boilers are multitubular, four being at each end of the engine-room space, arranged in pairs, with one funnel to each pair. There are five fire-grates in each boiler, 3 ft. 1 in. wide, with bars 5 ft. 6 in. long. The boilers being placed lengthways in the vessel, the firing-space, which is 11 ft. wide, is in the centre. The entire extent of the grate surface in the eight boilers is 677 square feet; and the heating surface measures 19,700 square feet. The bunkers are small, being made to contain only one day's coal, as the vessels can be supplied either at Holyhead or at Kingstown, during the interval between their arrival and departure. The space occupied in the length of the vessel by the engines and boilers is 108 ft., and this has been subdivided, by iron water-tight bulkheads, into three compartments, an arrangement suggested by Mr. Laird, and which has been found most beneficial in giving strength in a part of the vessel which might otherwise have been weak, and unequal to the severe strain of the powerful machinery working in the heavy seaway of the Irish Channel. The wheels, which are constructed on the feathering principle, with fourteen floats each, are 31 ft. in diameter at the outside of the floats, or 27 ft. to the centre of axis; and each float is 12 ft. long by 4 ft. 4 in. broad. On the trial trips, the engines worked at the rate of $25\frac{1}{2}$ revolutions per minute, under a steam pressure of 25 lbs. per square inch. The mean of the runs of the 'Leinster,' at the

measured mile in Stokes Bay, was at the rate of $20\frac{1}{2}$ statute miles an hour, a greater speed by upwards of one mile an hour than had been previously attained by any other vessel. The 'Connaught,' when subsequently tried at the measured mile in Stokes Bay, attained a higher result, the mean of her runs showing the speed of $20\frac{3}{4}$ statute miles per hour. *Vide* Table A.

The 'Ulster' and the 'Munster' were built by Messrs. Laird, on exactly the same lines as the 'Connaught.' The engines of these vessels were constructed by Messrs. James Watt and Co., of Soho, the same establishment from whence the engines proceeded for the first steam-vessels built for the Post Office for the performance of the Holyhead Mail Service. Boulton and Watt would have been somewhat surprised, if it could have been foretold that their successors would have been called on to construct engines tenfold the size of what they had made to be placed in vessels tenfold the tonnage of the 'Royal Sovereign' or the 'Meteor,' and for the same line of postal communication. The general arrangement of the engines in the 'Ulster' and the 'Munster' is nearly the same as of those in the 'Leinster' and the 'Connaught.' The cylinders are in diameter 7 ft., with a length of stroke of 96 in. The wheels are 33 ft. in diameter over all. The boilers have each six fireplaces, 2 ft. 6 in. wide, and the bars are 5 ft. 6 in. long, giving in the aggregate as large an extent of grate surface as in the others. The area of the heating surface is 18,033 square feet. One funnel is used for the four boilers of each compartment; and as the coals are carried on the top of the boilers, the entire space occupied in the ship by these engines and boilers is but 102 ft. These engines were erected on board the vessels in the Liverpool Docks. There is not any measured mile at that port for testing speed; but from a return supplied by Messrs. Watt and Co., of observations made on several trips, the rate attained appears to have been $17\frac{1}{2}$ knots, or 20·3 statute miles per hour, and the average performances of the 'Ulster' and the 'Munster,' contrasted with the average performances of the other vessels, fully prove that this in no degree overrates their speed, when going under the usual conditions of a trial ship.

The internal arrangements of the vessels were planned with the object of providing for the comfort and accommodation of the public, in the way best calculated to mitigate and, as far as possible, to prevent the sufferings so usually inseparable from the passage of the rough Irish Channel. For although the talented builders endeavoured to design a form which should be easy in a seaway, both they, and those for whom they were building, were well aware that it was utopian to expect, as many appear to have expected, with ships of even their large dimensions, a uniform horizontal position in tempestuous weather. Enlarged size has no doubt, in many cases, lessened the motion at sea; but the chief advantage in this instance is that it has afforded the means of providing reasonable accommodation for many passengers,—a want which had been so much felt with the previous smaller class of packets. The saloons and cabins in the new vessels are large, lofty, and well ventilated. The principal one is upwards of 60 ft. in length, by 17 ft. in breadth, and 9 ft. 6 in. in height, there being state-rooms on each side of the principal saloon. There are two commodious deck-cabins. The cabins for the second-class passengers are placed forward.

A better opportunity could not have been desired for attaining a good result, than the Holyhead and Kingstown mail line. There was sufficient depth of water at all times of the tide, with no natural obstruction to the navigation of the Channel; and the short distance needing no great weight of coal, and no cargo being carried, the vessels would at all times have very nearly the same uniform immersion.

The cost of the four ships to be provided, in accordance with the contract, was £75,000 each. The actual cost has, however, greatly exceeded the amount agreed to be expended by the Company, in consequence of the size of the vessels having been enlarged to upwards of 2000 tons, and the engines in about the same proportion; a change which has obtained increased accommodation for the public, and probably a superior performance of the vessels at sea.

One of the principal peculiarities, which render these vessels of so unique a class, is the post-office fitted for sorting letters during the passage. The space occupied for this purpose extends across the entire breadth of the vessel, and for the length of 30 ft., between the first and second class cabins. It is divided into two rooms, one for letters, and the other for newspapers. In these rooms the sacks are opened, the contents taken out and arranged by eight or ten sorters, under the direction of a head superintendent. The letters are stamped with the post-office packet brand, the postage label cancelled, and all the operations completed, so that the letters are ready for delivery, or to be forwarded to their destination, on the arrival of the vessel at Kingstown. About two hours are thus saved in the transmission of the mails, in consequence of their being made up on board, instead of after their arrival at the General Post Office in Dublin. Besides the gain in time thus secured for postal purposes, the main object to be attained was regularity; while for passengers, accommodation was perhaps even more to be valued than extreme speed. To fulfil all these conditions, it was necessary to have very large vessels, such only obviously allowing the requisite extent of accommodation; and experience had shown that the larger the vessel, when provided with adequate power, the less was the difference in the length of the passage at sea caused by severe weather.

The contract with the Postmaster-General had appointed January 1861 for the commencement of the improved service. But the vessels being in readiness some months sooner, it was commenced, by mutual agreement, in October 1860, and has since been continued without interruption. When two of the vessels, the 'Leinster' and the 'Ulster,' were completed and ready for duty, it was thought advisable to make a trial with them, by way of practice, in the performance of the old contract. Each performed the distance between the lighthouse on Kingstown Pier to the lighthouse at Holyhead, upwards of 65½ statute miles, in nearly the same time on the average, namely, the 'Leinster' in three hours and thirty-one minutes, and the 'Ulster' in three hours and thirty-two minutes, being respectively thirteen and twelve minutes less than the shortest monthly average of the 'Banshee' in 1848-49, and twenty and nineteen minutes less than the 'Llewellyn,' when the distance between the lights was one mile less than in 1860—the Holyhead breakwater not having then been in existence *. The gain in speed realized by the new vessels was therefore at the rate of from 1·2 to 1·7 mile per hour.

From what has been already stated, with regard to the speed of each of the vessels on their trial trips, when, as is usually the case on such occasions, the utmost power of the engines is exerted during the short time required for the run of a few miles, it may be readily seen that, for actual daily duty, the difference between the four vessels is inappreciable, a matter of paramount importance to a mail service. The extreme difference in the rate of speed on trial appears to have been about half a mile an hour, which would add but

* The courses are laid down on the plan of Holyhead Harbour attached to this communication.

six or seven minutes to the passage between Holyhead and Kingstown, taking the present course at 57 knots, or a little over $65\frac{1}{2}$ statute miles; the extension of the great breakwater having added more than a knot to the distance given in the Admiralty Returns as having been performed by the 'Banshee,' the 'Llewellyn,' and other packets in 1849–50. A speed of $17\frac{1}{2}$ knots, or 20 statute miles per hour, on the trial trip, allows a safe margin for making the passage commonly in four hours, the time proposed by Government; but this large margin has not in practice been found too much. Again, it may be observed, that there is a considerable difference in running a few times by the measured mile, when all is tasked for a short time to the utmost, and making a single complete passage of the Channel, even under favourable circumstances. Thus, while the 'Connaught' attained a speed of $20\frac{3}{4}$ statute miles an hour on her trial trip, her shortest passage of the Channel occupied three hours and fourteen minutes, being at the rate of about 20 miles an hour. The shortest passage of the 'Leinster' was made in three hours and twenty minutes; that of the 'Ulster' in three hours and eighteen minutes, and of the 'Munster' in three hours and twenty-six minutes. But the average performance of the vessels for the two years and five months, up to May 1863, during which they have been on service is still closer. Inclusive of all passages made in fogs, gales, &c.,

				h	m
The 'Connaught'	made	1064	in the average time of	3	51·5
The 'Leinster'	,,	919	,,	3	52·5
The 'Ulster'	,,	925	,,	3	55
and the 'Munster'	,,	920	,,	3	58·1

So close a performance by the four vessels, not identical, and not all from the same builders and engineers, could scarcely have been anticipated. The longest passage made in the severest gales has not exceeded five hours and forty minutes, and one vessel only has been that length of time on but two occasions. The previous packets were retarded by the weather to a far greater degree. The 'Banshee' has taken nearly eight hours to cross the Channel; the 'Llewellyn,' the 'Caradoc,' and the 'St. Columba' still more. Nearly four thousand passages have been already made up to May 1863, without collision, except on one occasion, which happily was not attended with very serious consequences. Experienced naval officers anticipated frequent and serious disasters; but the rate of speed, 16 miles an hour, though high for night-work, does not appear to have been too high for safety. The sense of greater responsibility, and the larger number of men engaged in the navigation and management of the vessels, must naturally induce additional precaution, as well as afford the means of guarding against danger. The facility with which these large vessels are handled and brought alongside the jetties is remarkable. The practised skill of the officers, and the quickness with which the engines are managed, frequently succeed in getting the vessels alongside, in making them fast, establishing the means of communication with the shore, and in landing the mails in three or four minutes.

The consumption of coal in the first few months was considerably in excess of the quantity originally estimated. Steam of from 25 lbs. to 28 lbs. pressure was then used, which not only required much extra coal, but severely taxed the durability of the boilers. Arrangements were therefore made to reduce the consumption to the amount stated in the estimates submitted to Government, on which the contract was founded. The result has been satisfactory, while the additional time occupied on the passages is but a few minutes, and they are still made on the average within the time allocated to

the sea service by the proposal of Government. The necessity of laying up the vessels more frequently for repairs has been also diminished, which is a matter of much importance, as they are of so unique a class, that in the event of more than two being laid up at the same time, it would be impossible to obtain an efficient substitute, and therefore the postal service might be exposed to some danger of interruption, if such circumstances were to continue for any length of time. The engines in the 'Ulster' and the 'Munster' were provided with superheaters, but experience has not shown any advantage resulting from their use, either as reducing the consumption of coal or tending to a superior performance. These vessels have made, up to May 1863, in the aggregate 1845 passages, in the average time of 3h. 56 min., and have consumed 30 tons 7 cwt. on the average of each, inclusive of the quantity required for raising steam, which is very considerable. The 'Leinster' and the 'Connaught,' without superheaters, have made 1983 passages, in the average time of 3 h. 52 min., and have consumed (inclusive of raising steam), on the average, 30 tons 1 cwt. of coal.

No breakdown has taken place with any of the engines. On two occasions some derangement occurred with the wheels. Very constant attention is given, during each "rest" after the usual term of duty, to the machinery and the boilers, so as to prevent the necessity of extensive repairs.

The principal trouble has arisen from the difficulty which appears to be experienced in obtaining sufficiently sound forgings for the large intermediate air-pump crank-shafts. As a precautionary measure, two duplicate shafts fitted with cranks had been included in the original order, one suitable for either pair of engines from each firm, so that no time might be lost in replacing one, if at any time it was found to be defective, or appeared to be doubtful. This was no needless precaution, as within the first year it was found necessary to condemn two shafts and to use the duplicates, and the vessels were ready within the week for service instead of being laid up for months. Two new spare shafts were immediately again ordered, and these have since been required; and another of steel, made by Mr. Krupp (of Essen), is also now in use. Thus, within the space of two years and a half, five of these costly pieces of work were condemned. It is but justice to the makers of the engines to state that they have met the case in the most satisfactory manner. No failure has hitherto occurred with any of the shafts supplied by the Mersey Steel and Iron Company, and they have done their full share of duty. Very great exertion was made by that establishment on one occasion to prepare a forging within the short space of three weeks, to replace one under peculiar circumstances, which rendered the utmost expedition important.

With regard to the ships, it is very satisfactory to be able to state that no repairs have so far been needed. They are now in as perfect condition, after the performance of their severe duty, as when they commenced in 1860. The frequency of docking, for the purpose of cleaning and coating, has afforded constant opportunity of examination, but painting only has been found necessary.

To maintain speed, it is obviously indispensable to keep the bottoms of the vessels clean; but as no docking accommodation has as yet been provided at Holyhead, and it being objectionable to remove the vessels from the station to the graving-docks of other ports, if possible to avoid doing so, the experiment of employing divers, while the vessels lay alongside the jetty, was tried last summer, and with some success. The growth of marine vegetation and the adhesion of marine animals, which take place rapidly in the summer months, were prevented to a considerable extent.

PARTICULARS OF TRIAL TRIPS. (Table A.)

	Banshee.	Llewellyn.	Victoria and Albert.	Leinster.	Connaught.
hen tried	10th Jan., 1848	15th May, 1848	23rd July, 1855	26th July, 1860	27th Sept., 1860
here tried.........	Long Reach	Noreand Mouse	Stokes Bay	Stokes Bay	Stokes Bay
aft of Water—					
Forward	8 ft. 8 in.	8 ft. 6 in.	13 ft. 10 in.	12 ft. 2½ in.	12 ft. 9 in.
Aft	9 ft.	9 ft. 2 in.	14 ft.	13 ft. 2½ in.	13 ft. 2 in.
ea of Midship Section.........	192 ft.	185 ft.	401 ft.	336 ft.	341 ft.
o. of Revolutions .	30·5	28·5	25·4	26·25 mean	25·5
essure on Safety-valve	19 lbs.	20 lbs.	23 lbs.	25 lbs. by gauge	26½ lbs. by gauge
cuum in Condensers.........	...	...	25 in.	25 in.	25½ in.
ominal Horse-power	350	350	600	720	720
dicated Horse-power	1,555	1,890	2,980	4,751	4,735
eed of Vessel—					
Knots.........	16·1	15·912	16·827	17·747*	18·079*
Statute Miles .	18·553	18·317	19·377	20·429	20·811

Report on the present State of our Knowledge of the Reproductive System in the Hydroida. By GEO. J. ALLMAN, *M.D., F.R.C.S.I., F.R.S., F.R.S.E., M.R.I.A., Regius Professor of Natural History in the University of Edinburgh*†.

FROM the time that Ehrenberg announced a sexual differentiation among the HYDROIDA, and assigned a significance which was very nearly the true one to those parts of their structure which are at present known to be destined for the formation of ova and spermatozoa, a marked progress set in in our knowledge of the phenomena, morphological and physiological, which occur among these animals; and the investigations of numerous observers, both in this country and abroad, have thus resulted in a very extensive, if not yet complete, acquaintance with a group of animals which are probably not surpassed by any in interest, whether we regard the singularity and beauty of their forms or the light which they seem capable of throwing upon various questions in morphology and physiology,—a group, however, which, if we would hope to attain to any important knowledge of the structure, functions, and relations of the animals which compose it, can alone be studied by laborious observation of these animals in their living state, and by unremitting and wearying microscopical dissections, while even this would lose half its value unless accompanied by faithful drawings, as the only means by which it is possible to give permanence to the characters of these frail and transitory organisms.

Many years' study of the HYDROIDA has, however, convinced me that the phenomena of their life-history have not all received their true interpretation;

* The mean of four runs.

† The greater part of the following Report was laid before the Cambridge Meeting of the Association, in Sept. 1862; it was only, however, at the following Meeting, August 1863, that it was possible to present it in its completed form.

and I have endeavoured to embody in the following Report the results of this study, so far as they regard reproduction, combining them with what has been added by the labours of others in the same field, so as to present, as far as possible, a comprehensive survey of this department of research.

Among the older observers, those to whom, during the last century, we are chiefly indebted for advancing our knowledge, both morphologically and physiologically, of the HYDROIDA, the names of Ellis and Cavolini stand conspicuous; while, during the present century, the labours of Sars, Ehrenberg, Lovén, Krohn, Kölliker, Gegenbaur, Steenstrup, Van Beneden, Dujardin, Leuckart, Fritz Müller, Claparède, and others on the Continent, Agassiz, Clark, and M'Crady in America, and in our own country those of Dalyell, Huxley, Alder, Hincks, Busk, Strethill Wright, and Greene, have thrown new and important light upon their structure and functions, and have led to the determination of the true import of many phenomena which would otherwise have remained imperfectly understood.

Among the works which have of late years done most in the simple descriptive zoology of the HYDROIDA must be mentioned the 'Monograph of the British Naked-eyed Medusæ,' by Edward Forbes, and the 'History of the British Zoophytes,' by George Johnston—works whose specific determination of the British forms have greatly smoothed the way towards their profounder study, affording to the anatomical worker of the present day the same kind of aid which the zoological descriptions in Ellis's classical 'Essay on the Natural History of Corallines' gave to the earlier investigators.

In combining anatomical with zoographical description, the 4th volume of the great work of Agassiz (Contributions to the Natural History of the United States of America, 1862) holds a preeminent place in the fulness of its descriptions and the profuseness and excellence of its illustrations; and though I shall have occasion, in the following pages, to dissent from some of the views of the celebrated American zoologist, I must here express my admiration of this fine contribution to the zoological literature of our day.

Besides the advantages I have derived from consulting the works of the various authors named above, I must express my thanks for much valuable information derived from personal correspondence with numerous friends, especially Professors Huxley and Greene, the Rev. Thomas Hincks, Mr. Alder, and Mr. Busk.

Some apology may be deemed necessary for the number of new terms introduced into the following pages; I do not believe, however, that I have employed one which could be advantageously dispensed with. Among the means which have tended most to advance a philosophic zoology is a well-selected and accurately defined terminology; while few things have tended to retard it so much as ill-selected and loosely applied terms. A rigidly defined and significant terminology not only facilitates in a way which it alone can do the communication of scientific ideas, which would otherwise have to be expressed by cumbrous circumlocution and phrases which fail to impart definite ideas, but, like the symbols in algebra, it even becomes a direct instrument in the investigation of truth.

The subclass HYDROIDA of the following Report includes the orders *Hydrida*, *Tubularida*, *Campanularida*, and *Sertularida*, being so far exactly coextensive with the *Hydroida* of Johnston. It necessarily embraces, however, most of the so-called naked-eyed Medusæ; for a large proportion of these are now known to be the free zooids of polypoid forms belonging to the *Tubularida* and *Campanularida*, while those which have not yet been so traced—provided we have no reason to regard them as the free zooids of the SIPHONOPHORA—and

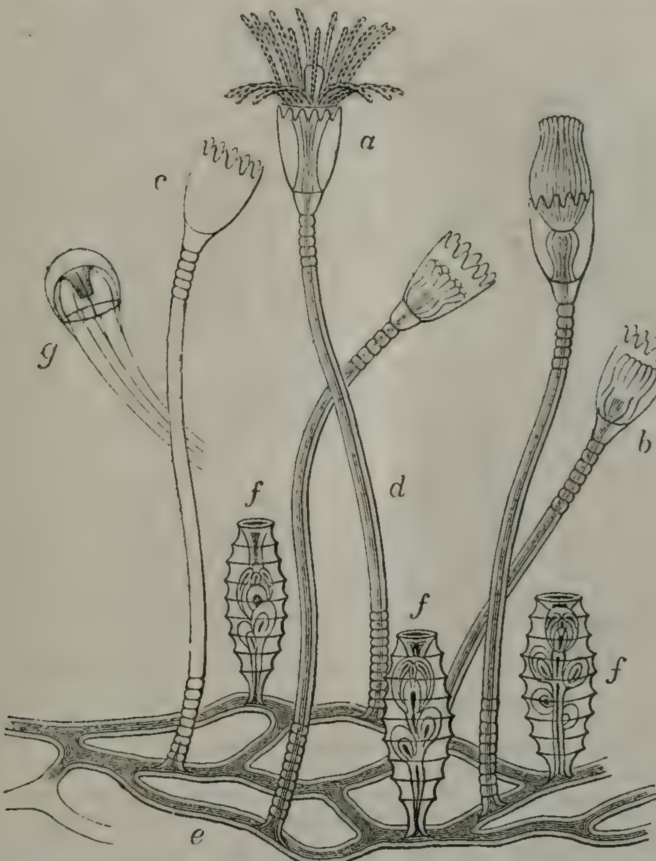
even those which may be proved to be developed directly from the egg, cannot, in a philosophical system, be separated from the others*.

I. Sketch of the general Morphology of the Hydroida.

The Hydroida, wherever our knowledge of them is sufficiently complete to justify us in arriving at any conclusion regarding the entire life of the individual, are all, with, so far as we yet know, only a single exception, composite animals at one period of their existence, each consisting then of an assemblage or colony of zooids† in organic union with one another. The colony thus formed constitutes the "hydrosoma" of Huxley.

The associated zooids are always of two kinds (fig. 1). In one (*a*, *b*, *c*, *d*, *e*)

Fig. 1.—*Campanularia Johnstoni*, showing the trophosome and gonosome.



a, *b*, *c*, *d*, *e*, various parts of the trophosome, and *f*, *g*, of the gonosome.

a, Polypite expanded; the tentacles are in a single verticil, but when fully extended are held with the alternate one elevated and depressed; *b*, polypite retracted; *c*, empty hydrotheca; *d*, stem supporting the polypite and hydrotheca; *e*, creeping stolon; *f*, gonangia containing gonophores, which in the present species are in the form of complete gymnophthalmic medusæ; *g*, one of these medusæ just after its escape from the gonangium.

* The recent coral-group *Tabulata*, and the extinct one *Rugosa*, are referred by Agassiz to the Hydroida. Our knowledge of their structure, however, is as yet very imperfect; and as we know nothing whatever of their generative phenomena, I shall make no further reference to them in the Report.

† For the introduction of the very convenient term "zooid" into the language of zoology

the zooid is destitute of all power of true or sexual generation, and has as its proper function the nutrition of the colony. The other group of zooids (*f, g*) has nothing to do with the nutrition of the colony; it has as its proper function true generation, and the zooids which compose it give origin to the generative elements—ova and spermatozoa, either directly or after having first developed a special sexual bud. For the whole assemblage of the former or nutritive zooids I propose the name of "*trophosome*"*, while to the latter or generative zooids I shall give the name of "*gonosome*"†. Every hydroid, therefore, with whose life-history we are acquainted, consists essentially, with the solitary exception already alluded to, and which will be afterwards more particularly mentioned, of a trophosome destined for the preservation of the individual, and a gonosome for the perpetuation of the species‡.

The proper nutritive zooids (fig. 1 *a, b*; fig. 2 *a*) which constitute the essential part of the trophosome of the HYDROIDA have long been known, in common with the zooids of the ACTINOZOA, by the name of Polypes. It will be more convenient, however, to restrict this term to the ACTINOZOA, to which Reaumur, borrowing it from Aristotle, who used it for the cuttle-fishes, originally applied it; while we may employ the term "*polypite*" as proposed by Huxley§ for the alimentary zooids of the HYDROZOA.

The polypite consists essentially of a digestive sac, opening at one end by a mouth, and prolonged at the opposite into a simple or branched tube which is common to all the zooids of the colony. Behind the mouth are situated, in almost every instance, tubular offsets from the digestive sac. These are known as "*tentacula*"; they are usually arranged in a single verticil (*Campanularia, Sertularia*, &c.), sometimes in two, one behind the other (*Tubularia*), while they are sometimes scattered over the body of the polype (*Coryne*, &c.), or are partly verticillate, partly scattered (*Pennaria*)||.

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we are indebted to Prof. Huxley, who, in defining the "individual" as "the total result of the development of a single ovum," proposed to designate by the term zooid all more or less independent forms which may be included as elements in this total result. (See Huxley, Observations on *Salpa*, &c., in Phil. Trans. 1851; Lecture on Animal Individuality, Ann. Nat. Hist. June 1852; and his review of J. Müller's Researches on the Development of the Echinodermata, in Ann. Nat. Hist. July 1851. See also Carpenter, Princ. Gen. and Comp. Physiology, 1851, p. 906, and Brit. and For. Med. Chir. Rev. for Jan. 1848 and Oct. 1849, where he clearly supports the same idea, using the expression "a generation" for all that intervenes between one act of true or sexual generation and another.

The distinction between a "zooid" and an "organ" is not always easy, and may indeed sometimes appear to be arbitrary. I believe, however, that we may regard as a zooid every portion of an animal which is not the immediate result of true sexual generation, and is yet capable of independent existence, as well as such portions which, though never attaining to independent existence, yet homologically represent independent forms. In this sense not only are the free medusiform buds of the HYDROIDA true zooids, but we must also regard as such the fixed polypites and those fixed gonophores which never attain a developed medusiform structure, as well as the simple generative sacs which are developed on the radiating canals of *Obelia, Thaumantias*, &c. (see p. 401).

* Τρέφω, to nourish, and σῶμα, body.

† Γόνος, offspring, and σῶμα.

‡ The trophosome of the HYDROIDA admits of an easy comparison with that of the SIPHONOPHORA; but among the zooids which are associated in the trophosome of the SIPHONOPHORA there are, in the Calycophoridæ and many Physophoridæ, besides those constructed for the immediate reception from without of the nutritive material which constitutes the food of the colony, certain others which are destined for locomotion and protection, and whose part in nutrition is accordingly subordinate to that of the former.

§ The 'Oceanic Hydrozoa,' published by the Ray Society, 1859.

|| In the Calycophoridæ and most Physophoridæ the tentacles of the polypite are reduced to a single one arising from its base, while the polypites of the Velellidæ and Physalidæ are altogether deprived of tentacles, their place being here apparently taken by analogous fili-

It is rare for any other form of zooid besides the polypite to enter into the composition of the trophosome. In a few genera, however (*Plumularia* and its allies), we find associated with the polypites certain very remarkable zooids, whose function, though obscure, is more likely to be connected with the nutrition of the colony than with anything else. The bodies in question have been named "*nematophores*" by Busk*. They are situated upon certain definite points of the trophosome, and consist of minute tubular receptacles containing a soft granular protoplasm, and frequently, though not always, a cluster of large thread-cells. The protoplasm which fills these receptacles can spontaneously emit prolongations of its mass in no way distinguishable from the "pseudopodia" emitted by the true Rhizopoda. In fact, the contents of the nematophores present in this respect no appreciable difference from the protoplasm composing the body of an Amœba. The thread-cells, however, though apparently immersed in the protoplasm, do not seem to be ever carried out in the pseudopodial prolongations, and it is probable that the portion of the contents of the nematophore with which they are in immediate connexion does not participate in the power of emitting pseudopodia.

The trophosome may consist of only a single polypite (*Corymorpha*), or, what is by far the most frequent condition, it may consist of many associated into a compound group or colony. All the zooids of a colony, both those belonging to the trophosome and those belonging to the gonosome, are kept in organic union with one another by a common connecting tubular basis (fig. 1 *d*, *e*). To this common basis of communication I have elsewhere† given the name of "*cœnosarc*."

Both zooids and cœnosarc are composed of two membranes, an outer or "*ectoderm*" and an inner or "*endoderm*," the ectoderm having its free surface in direct relation with the outer world, while the free surface of the endoderm is turned inwards and forms the boundary of the gastric cavity and of all its prolongations through the organism‡. A similar composition may be demonstrated not only in all the rest of the Hydrozoa, but in the whole group of the Cœlenterata. For the important generalization which thus asserts the composition of every cœlenterate animal out of two membranes—a generalization which forms the basis of the whole morphology of the Cœlenterata—we are indebted to Professor Huxley, who first enunciated it as a great anatomical truth§.

The ectoderm invariably contains imbedded in it the peculiar bodies known as thread-cells, which are frequently aggregated in definite groups, very characteristic of the species in which they occur. A fibrillated contractile tissue, resembling non-striated muscular fibre, may also in a great many instances be demonstrated in connexion with the ectoderm.

In every member of the Hydroida with whose trophosome we are acquainted, excepting only the freshwater *Hydra* and probably also *Nemopsis*,

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orm organs, which occur at a distance from the polypites, and arise from the common connecting basis of the colony.

* Busk, MS. Lectures on Comparative Anatomy delivered in the Royal College of Surgeons, London.

† "On the Anatomy and Physiology of *Cordylophora*," Phil. Trans. 1853.

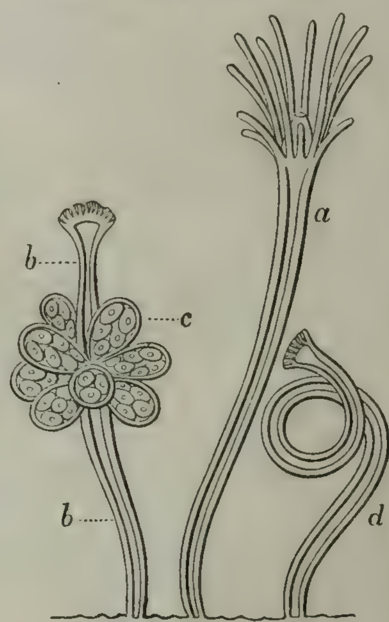
‡ From this generalization, however, we must except the "Nematophores," in whose imple granular amœboid protoplasm no differentiation into ectoderm and endoderm can be etected.

§ See his Memoir on the Anatomy and Affinities of the Medusæ, Phil. Trans., June 1849; lso his 'Oceanic Hydrozoa,' published by the Ray Society, 1859, and Lectures on General at. Hist., in the 'Medical Times.'

with its curious free trophosome, described by McCrady*, and *Acaulis*, another genus with a free trophosome, described by Stimpson†, the ectoderm excretes from its outer surface an unorganized pellicle chemically identical with chitine, and forming an external tubular investment for the soft organized ectoderm. The extent to which the ectoderm is covered by it varies: in some cases it is confined to the cœnosarc; in others it extends not only over the entire cœnosarc, but is often continued for a greater or less extent, and in a more or less modified form, over the various zooids of the colony. In the *Sertularida* and *Campanularida* (fig. 1) it forms cup-like receptacles—the "*hydrothecæ*" of Huxley, into which the polypites are retractile. It is invariably absent from those zooids which have detached themselves from the colony, in order to lead an independent life in the open sea‡. For this unorganized excretion, which must be placed in a totally different category from that of the ectoderm and endoderm, I propose the name of *periderm* §.

Two different classes of zooids may combine to make up the gonosome‖. To the more important and only constant one of these classes (fig. 2 *c*) I have elsewhere¶ given the name of *gonophore*, a term which I shall continue to employ in the present Report. The gonophore is either the *ultimate generative zooid*, giving origin directly to the generative elements, or it gives origin to these elements through the medium of a special sexual bud which is developed from it. Though possessing intimate homological relations with the polypite, it is nevertheless constructed upon a special type, and may be in every case referred to the plan, frequently much modified, of the so-called "gymnophthalmic medusa." It often separates itself from the rest of the hydroid, and then lives as a free locomotive zooid in the open sea (fig. 1 *g*).

Fig. 2.—Group consisting of three zooids from a colony of *Hydractinia echinata*, taken from near the margin of the colony.



a, Alimentary polypite; *b b*, gonoblastidium bearing, *c*, the gonophores; *d*, spiral polypite, developed close to the margin of the colony. The three zooids are connected to one another by a common basal expansion or cœnosarc.

The other class (fig. 2 *b*) is not necessarily present. It consists of peculiarly modified polypites, having their alimentary function more or less suppressed, but never detaching themselves from the trophosome so as to enjoy an independent existence. They are the "*gonoblastidia*" of Huxley.

The gonophore is always borne as a bud, either directly upon some part of the trophosome, or upon the gonoblastidium, or upon another gonophore which is not then the ultimate generative zooid.

* "Gymnophthalmata of Charleston Harbour," in Proc. Elliott Society of Nat. Hist. of Charleston, South Carolina, 1859.

† "Synopsis of the Marine Invertebrata of Grand Manan," in Smithsonian Inst. vi. 1854.

‡ It is also entirely absent from the SIPHONOPHORA. § περί, around, and δέρμα, skin.

‖ Without including the peculiar receptacles in *Plumularia* and its allies, described below under the name of "*corbulæ*." ¶ Proc. Roy. Soc. Edinb. Session 1857–58.

The gonophores, though presenting manifest homological parallelism with the polypites, have a very different form, fitting them for the special functions to which they are destined. They are constructed essentially on the plan of a gymnophthalmic medusa, but vary greatly in the degree of completeness in which this plan is expressed in them. They may be primarily referred to one or other of two principal types, based respectively upon their greater or less approach to the completely formed medusa. The peculiar condition by which one of these types is characterized may be named "*phanerocodonic*" *, while that which distinguishes the other may be designated as "*adelocodonic*" †—conditions, however, which, it must be borne in mind, pass into one another by numerous gradations.

The phanerocodonic condition is found in those gonophores whose essential part is a typically developed medusa (fig. 1 *g*), and which are distinguished by having a well-developed umbrella, provided with the wide aperture or "*codonostome*" ‡ which characterizes this part of the structure in the complete medusa; the umbrella, except in one remarkable form—that presented by *Clavatella*, Hincks (fig. 3), and by *Eleutheria*, Quatrefages—being eminently contractile and fitted for natation. The adelocodonic condition is found in the bodies to which I have elsewhere given the name of *sporosac*; these bodies have either no umbrella (fig. 2 *c*), or, if this be present, it is in an incompletely developed state, never provided with a wide open codonostome, and quite incapable of acting as a locomotive organ.

The phanerocodonic gonophores, in by far the greater number of instances, detach themselves, either in whole or in part, from the trophosome or gonoblastidium after they have attained a certain degree of maturity, and lead henceforth an independent existence, during which they increase in size, often develope new parts, and sooner or later give origin to ova or spermatozoa.

In some cases, however, they develope and discharge their reproductive elements while still attached, and then wither away, without ever becoming free, notwithstanding their well-developed contractile umbrella apparently fitting them for an independent natatory existence. That there is, however, no essential difference between these two forms is evident from an observation of Agassiz, who found the gonophores of *Coryne mirabilis*, Agass., in the earlier months of the year, detach themselves from the trophosome and swim away as gymnophthalmic medusæ before the development in them of ova or spermatozoa; while, somewhat later, he has seen the gonophores attain to sexual maturity without ever becoming free.

The free phanerocodonic gonophore is in a single instance ambulatory; in all others it is natatory, locomotion being effected by alternate systole and diastole of the umbrella §. In the ambulatory form the umbrella is incapable of evident systolic and diastolic movements, and locomotion is performed by marginal tentacles peculiarly modified for creeping over solid bodies. This very exceptional form has been met with only in *Clavatella*, whose trophosome has been discovered by Hincks, and in the nearly allied *Eleutheria* of Quatrefages, whose trophosome has not yet been detected.

While all the leading features of a gymnophthalmic medusa are thus at once obvious in the phanerocodonic gonophore, the adelocodonic gonophores,

* Φανερὸς, manifest, and κώδων, a bell. † Ἄδηλος, not apparent, and κώδων.

‡ Κώδων, and στόμα, a mouth.

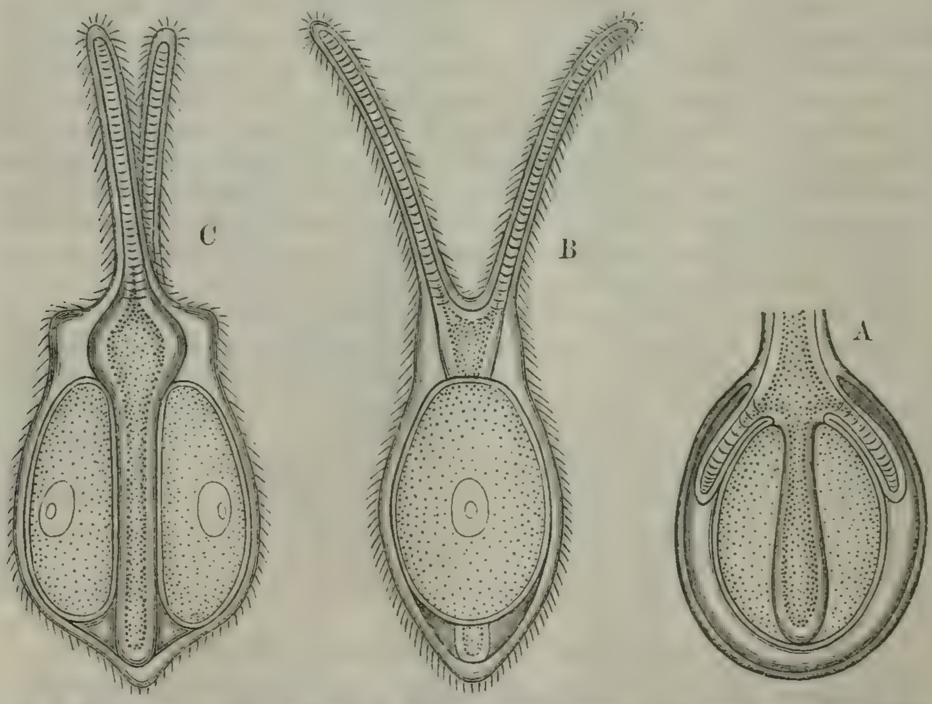
§ The gonophores of the Calycophoridæ properly come under the designation of phanerocodonic, though they may never become free, and though we find them departing somewhat from the typical form of the gymnophthalmic medusæ by the non-development of the marginal appendages of the umbrella.

on the other hand, present the medusoid structure only in a disguised or undeveloped condition. They have the form of sacs, and, except in a single known instance, the whole gonophore remains permanently attached to the trophosome, giving rise within it to the generative elements, which, after attaining

Fig. 3.—Ambulatory medusa of *Clavatella prolifera.*

a certain degree of maturity, are ultimately discharged from its cavity. The single exception is afforded by the genus *Dicoryne*, Allm. (fig. 4), in which, before discharging its generative products, the gonophore liberates itself from its external investment or ectotheca, and thus becoming free, swims about actively by the aid of vibratile cilia.

Fig. 4.—Free locomotive sporosac of *Dicoryne.*



A, Male sporosac, still enclosed in its ectotheca. B and C, female gonophores after liberation from the ectotheca, swimming on the open sea; they represent two views of the same gonophore in planes at right angles to one another.

Though it is necessary to distinguish the gonoblastidia from the polypites, it cannot be overlooked that they pass into them by certain transitions. Agassiz* describes a well-developed mouth in the so-called fertile polypites or gonoblastidia of the *Hydractinia polyclina* of the North American coast, and it is doubtful whether even in our *Hydractinia echinata* the nutritive function is ever absolutely suppressed in the otherwise very characteristic gonoblastidia of this species. In certain *Eudendria* the polypites, which carry the gonophores grouped round their base, present a perfectly developed form while the gonophores are young; but as these continue to grow, the polypites which carry them frequently become atrophied, losing their tentacles and mouth, and by the time the gonophores have attained maturity the polypites have assumed the condition of gonoblastidia. Again, among the *Sertularida*, we find in *Halecium halecinum* the gonoblastidium, which here becomes a "blastostyle" (see p. 370), developing from its summit a pair of perfect polypites with tentacles and mouth. These, however, are all exceptional cases, and do not render less valid the association of the gonoblastidium with the gonosome rather than with the trophosome, while they are important as showing the homological identity between the polypite and the gonoblastidium.

When we compare with one another the various forms of phanerocodonic gonophores, we shall see that they are divisible into two important groups. In the gonophores belonging to one of these groups the generative elements are produced directly by the gonophore itself, being developed between the endoderm and ectoderm of its manubrium (fig. 8, p. 369); while in those belonging to the other group they are not produced directly by the gonophore, which is then, properly speaking, non-sexual, but are found in a special sexual bud to which this non-sexual gonophore itself gives rise (figs. 17 & 18, p. 401). It is necessary to distinguish these groups; and I shall accordingly designate the former or sexual form of phanerocodonic gonophore by the name of *gonocheme*†, while to the latter I shall give the name of *gonoblastocheme*‡.

Whether the entire gonosome remains during its whole lifetime connected with the trophosome, or becomes in any part an independent zoöid, it is manifest that it constitutes an essential element in the character of the species, and the study of no one species of hydroid can be regarded as complete unless it embrace both trophosome and gonosome. Since, however, in many cases we are acquainted with only the free gonophore, not having yet discovered the trophosome to which it belongs, while in other cases the trophosome alone is known to us, we have been in the habit of treating such instances in our systems without regard to the missing zooids, and as if they afforded examples of independent species; but it must never be forgotten that the data on which we thus assign to them the rank of determinate species, or even genera, are insufficient for the purposes of a philosophic system: such genera and species must be regarded as purely provisional; for the zoologist is no more justified in accepting such incomplete characters as sufficient for the accurate determination of his hydroid, than would the botanist be in regarding the flower alone on the one hand, or the root, stem, and leaves alone, on the other, as affording characters sufficient for the definition of any flowering plant whose exact determination he would attempt.

* Contrib. to the Nat. Hist. of the United States, vol. iv.

† Γόνος, offspring, and ὄχημα, a carriage.

‡ Γόνος, βλαστὸς (a bud), and ὄχημα.

II. Morphology of the Gonophore.

A. *Parts of an adelocodonic gonophore.*

An adelocodonic gonophore, when fully developed, consists of the following parts (see fig. 5 A, and fig. 6 A, B, C):—

1. An external membranous closed sac, *ectotheca**.
2. A second sac lying immediately within the ectotheca, *mesotheca*†.
3. A system of canals which permeate the walls of the mesotheca, *gastrovascular canals.*
4. A third sac, internal to the mesotheca, *endotheca*‡.
5. The generative elements (*ova* or *spermatozoa*), contained immediately within the endotheca.
6. A hollow process which occupies the axis of the gonophore, whose cavity is in communication with the somatic cavity of the trophosome, and round which the generative elements are produced, *spadix*§.

It is not usual, however, for the adelocodonic gonophore to possess all the parts here enumerated, the mesotheca and gastrovascular canals in particular being often entirely suppressed. The only absolutely constant parts are spadix, endotheca, and generative elements.

B. *Parts of a phanerocodonic gonophore.*

In a completely developed phanerocodonic gonophore the following parts may be distinguished (see fig. 5 B and fig. 6 D):—

a. An external membranous closed sac, *ectotheca.*

b. Within the ectotheca a peculiar body known as a *gymnophthalmic medusa.*

The gymnophthalmic medusa, which thus constitutes the essence of the phanerocodonic gonophore, consists of the following parts:—

1. An open contractile bell or disc, *umbrella.*
2. A central hollow body hanging from the summit of the umbrella-cavity, and bearing a mouth at its free extremity, *manubrium*‖.
3. A system of canals excavated in the substance of the umbrella, and lined with endoderm. They consist of a set of radiating canals and of a circular canal: the former are in by far the majority of cases four in number, or some multiple of four; they open by their proximal extremities into the base of the manubrium, and thence extend at exactly equal intervals towards the margin of the umbrella, while the circular canal runs round the umbrella immediately within its margin, and receives the distal extremities of the radiating canals which here open freely into it. These two sets, radiating and circular, constitute the *gastrovascular canals.*
4. Contractile *tentacula* which spring from the margin of the umbrella.
5. Either accumulations of pigment-granules, named *ocelli*, which occur at the base of the tentacles, and in which a refractile body is occasionally imbedded, or else peculiar capsules, *lithocysts*, which are attached to the margin of the umbrella, and enclose one or more transparent refractile corpuscles.
6. A membranous extension (*velum*) of the margin of the umbrella over

* Ἐκτὸς, outer, and θήκη, a sheath.

† Μέσος, middle, and θήκη.

‡ Ἔνδον, within, and θήκη.

§ Σπάδιξ, the closely crowded spike forming the inflorescence of a palm-tree, &c.

‖ *Manubrium* (Latin), a handle. It is the "peduncle," "proboscis," "stomach," &c., of authors. The term manubrium was suggested by me some years ago (Proc. Roy. Soc. Edin. 1858), in order to obviate the incorrect or equivocal significance which attaches itself to the names usually employed for this part.

the mouth of the bell, where it forms a thin muscular diaphragm, perforated in the centre by a circular opening of greater or less diameter.

7. Generative elements *.

In the description here given of the phanerocodonic gonophore, the somewhat aberrant group of medusæ which constitutes the family of the *Æginidæ* is not included; for these medusæ, while further research will probably succeed in referring them to polypoid trophosomes, have not as yet in any case been actually so traced. (See below, p. 418.)

We have already seen that the phanerocodonic gonophore may be a truly sexual zooid, which will then always give origin to ova or spermatozoa by the direct development of these elements between the ectoderm and endoderm of its manubrium (see fig. 5 B), without the intervention of any specialized bud, and will accordingly in this respect entirely correspond with the adelocodonic forms. It is to these properly sexual phanerocodonic gonophores that I have given the name of "gonocheme." Of this form we have examples in the types which have been described by authors under the names of *Sarsia*, *Steenstrupia*, *Oceania*, &c. (figs. 6 D, 8, & 16).

A large number of free gymnophthalmic medusæ, however, some of which are known to proceed from polypoid trophosomes, are properly non-sexual, and cannot give origin to the generative elements without the previous development of a special sexual bud. The sexual bud is borne upon some part of the course of the radiating canals; and it is this bud which is the true physiological equivalent of the adelocodonic gonophore and of the sexual form of phanerocodonic gonophore. Examples of this phenomenon may be seen in those medusæ which have been included by authors under the types of *Obelia*, *Eucope*, *Thaumantias*, &c. (figs. 1 *g*, 17, & 18).

It is to these free medusæ, which, while they are themselves properly non-sexual, give origin, like the gonoblastidium of *Hydractinia*, to sexual buds, but which, unlike the gonoblastidium, are endowed with locomotive powers, so that they carry these buds from place to place by the contractions of their umbrella, that I propose to give the name of "gonoblastocheme"†.

In the account here given of the gonoblastocheme, I have confined this term to such forms of medusæ as develope distinct sexual buds upon the radiating canals. In some of those medusæ, however, in which the reproductive elements are produced between the ectoderm and endoderm of the manubrium, we find a greater or less tendency to a differentiation of the reproductive mass from the general walls of the manubrium. This may be seen, for example, in certain forms of the *Oceania*, *Turris*, and *Lizzia* types, in which the ova or spermatozoa are developed in more or less specialized, frequently convoluted lobes of the manubrium, while in some, as in *Nemopsis*, Agass., these lobes are continued from the manubrium for some distance along the course of the radiating canals. I am not, however, yet prepared to place these cases in the same category with the true gonoblastocheme; for I have not had an opportunity of examining the structure of the manubrial

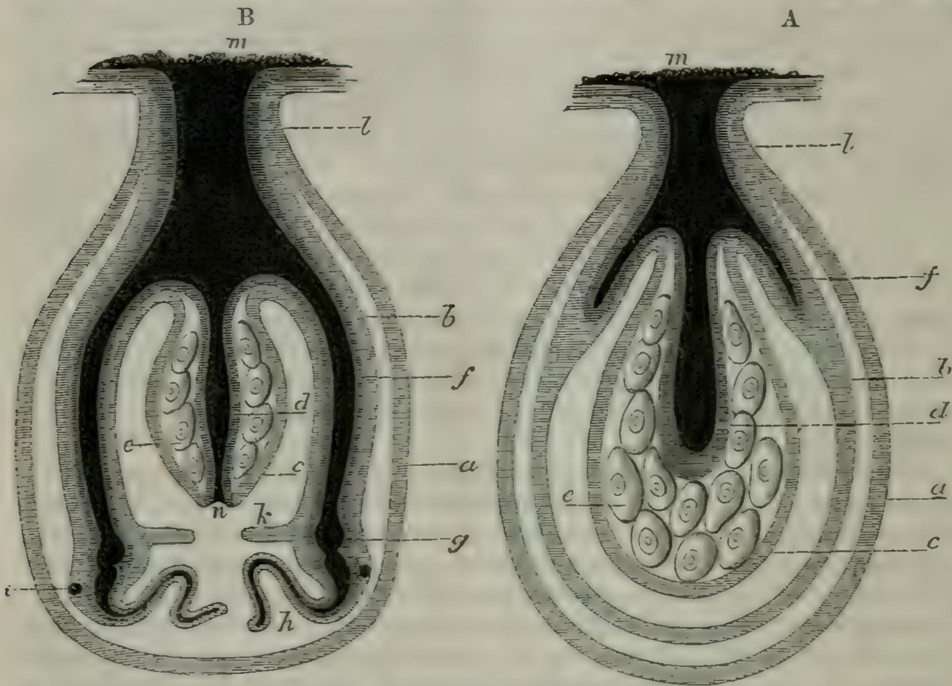
* The structure above described is that of the phanerocodonic gonophore in its most completely developed form, such as we meet with it in many of the *Tubularida* and *Campanularida*. Such complete differentiation, however, is not always attained even in the HYDROIDA, while among the SIPHONOPHORA the margin of the umbrella in the *Calycophoridæ* carries neither tentacles, ocelli, nor lithocysts, and the manubrium developes, at least usually, no mouth upon its extremity.

† In order to avoid complicating the subject, I have deemed it better to leave out of view the question as to whether the particular medusæ under discussion have been derived from a polypoid trophosome, or are the direct result of the development of an ovum. (See below, p. 417 &c., where this question of the origin of the medusæ is fully treated.)

lobes, so as to make out with certainty whether they be homologous with proper sporosacs. They may ultimately prove so: but until then it will be safer to restrict the term "gonoblastocheme" to those forms to which I have here applied it. When it shall be shown that specialized sexual zooids are developed from the manubrium, the same term must then be extended to the medusæ in which this phenomenon can be proved to occur.

Besides giving origin to their generative elements in special sexual buds developed on the radiating canals, the gonoblastocheme differs still further from the gonocheme in the almost universal absence of "ocelli" on the bases

Fig. 5.—Diagrammatic sections of adelocodonic and phanerocodonic gonophore.



A, Adelocodonic gonophore. B, Phanerocodonic gonophore.

a, ectotheca; *b*, mesotheca or umbrella; *c*, endotheca; *d*, spadix; *e*, ova; *f*, radiating gastrovascular canals; *g*, circular gastrovascular canal seen in transverse section; *h*, marginal tentacle; *i*, ocellus in bulbous base of tentacle; *k*, velum; *l*, peduncle of gonophore; *m*, general cavity of cœnosarc; *n*, mouth.

In both sections the endoderm is distinguished from the ectoderm by giving it a darker shade.

of the tentacles, and the presence of "lithocysts," which are developed on the intertentacular spaces of the umbrella margin*.

C. *Homological parallelism between the sporosac and the medusa, and between the gonophore and the polypite.*

While it will be found very convenient to insist upon the differences pointed out above between the phanerocodonic and the adelocodonic gonophores, it must

* An exceptional condition is presented by *Thaumantias* as limited by Gegenbaur, and by *Slabberia*, Forbes, in both of which ocelli are present and lithocysts absent, though the medusæ belong to the type of the gonoblastocheme; while in *Tiaropsis diademata*, Agass., another medusa of this type, a well-defined pigment-spot has been described by Agassiz as existing in the base of the lithocyst, a statement which I can confirm by my own observation on an undescribed species of *Tiaropsis* captured on the Firth of Forth.

not be supposed that these two forms are constructed upon plans widely different from one another. We find, on the contrary, that the most exact parallelism admits of being demonstrated between them; for though they may at first sight appear very different, it can nevertheless be shown that the closed generative sac of a *Clava* or a *Hydractinia* is an easily understood modification of a medusa*.

In comparing the two classes of gonophores with theview of determining their homological relations, their composition out of the two membranes ectoderm and endoderm must be carefully kept in mind.

Commencing with the central parts of a phanerocodonic gonophore (fig. 5 B), and comparing these with the central parts of an adelocodonic gonophore (fig. 5 A), we shall find that in the former we have a manubrium in the form of a more or less elongated tubular body occupying the axis of the gonophore. The walls of the manubrium are composed of two layers, an internal or endodermal layer and an external or ectodermal; and in all phanerocodonic gonophores of the sexual type (gonochemes) these two layers become ultimately more or less separated from one another by the development of the generative elements between them.

In the adelocodonic gonophore also we have a double-walled tubular body occupying the axis; but while in the phanerocodonic gonophore this body is in almost every case perforated by a terminal mouth, in the adelocodonic forms it is completely closed. The generative elements are here also developed between the two layers exactly as in the gonocheme; but, in consequence of the absence of a mouth, the central organ assumes, by the increasing volume of these elements, the appearance of a single-walled sac, filled with ova or spermatozoa, and having a cæcal diverticulum (spadix) plunged into the middle of the mass. This cæcal diverticulum is plainly the equivalent of the endodermal portion of the manubrium in the phanerocodonic gonophore, while the wall of the sac (endotheca), which thus immediately confines the generative elements, represents the ectoderm of the same organ.

The umbrella and gastrovascular canals of the phanerocodonic gonophore have their equivalents in the mesotheca and canals of the adelocodonic gonophore, when these happen to be present, though in many cases they are never developed; while the ectotheca holds exactly the same position and relations in the two forms.

It would seem that in no case is a velum or its homologue developed in the adelocodonic gonophore, while the marginal tentacles of the phanerocodonic forms are, except in the "meconidium" (see below, p. 376, fig. 12), also without their representative in the sporosac; for the tentacula-like tubercles which crown the summit of the adelocodonic gonophore of some of the *Tubularidæ* (*Tubularia coronata* for instance) are of an entirely different significance, being merely processes of the ectotheca.

We are thus enabled to trace a close parallelism between the two kinds of gonophore; but another comparison of great interest in this inquiry here suggests itself, that, namely, between the gonophore and the polypite. Now there

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Oceania octona, Fleming, and *O. turrita*, Forbes, medusæ belonging to the type of the gonocheme, are, on the other hand, described by Forbes as having a lithocyst imbedded in the tentacular bulb just below the ocellus.

* It is now many years since I endeavoured to demonstrate that the so-called "ovarian vesicles" of the *Tubularida*, and the fixed sacs contained within the gonangium of the *Sertularida* and *Campanularida*, were in all cases strictly homologous with the free medusæ—that they possess a true medusal structure in a more or less degraded or disguised condition. ("On the Anatomy and Physiology of *Cordylophora*," Phil. Trans., June 1853.)

can be little difficulty in finding in the body of the polypite the homologue of the manubrium of the medusa*; but the equivalents of the umbrella and gastrovascular canals of the medusa are not at first sight so obvious. I believe, nevertheless, that these are not totally unrepresented in the polypite. It will be kept in mind that the tentacula of the polypite are merely tubular radiating prolongations of the digestive cavity, though with the cavity of the tube usually more or less obliterated by the peculiar condition of the endoderm, and that for some distance from their origin they are necessarily included in the thickness of the body-walls of the polypite. Now this included portion I regard as the true representative of the radiating canals of the medusa; and if we were to imagine the ectoderm of the polypite in a *Eudendrium* or *Campanularia* to acquire unusual thickness in a zone corresponding in position to the roots of the tentacles, we should have a disc-like extension of the polypite traversed in a radiating direction by tubular extensions of the endoderm which lines the body-cavity of the polypite, and this disc would only need to become still further expanded in order to show itself as an unmistakeable umbrella, with radiating gastrovascular canals, while the proboscidiform extension of the body, which in these genera advances far in front of the base of the tentacles, would resemble in all essential points the manubrium of the medusa.

Now the commencement of such an expansion is evident in the polypite of many *Campanularidæ*, while in *Laomedea flexuosa*, Hincks, and *Campanulina* (*Laomedea*) *acuminata*, Alder, the ectoderm of the body is actually extended as a thin disc for a considerable distance in the plane of the tentacles, which acquire in consequence the appearance of being connected at their bases by an intervening web.

While the portion of the tentacles included in the thickness of the body-wall of the polypite will thus be the equivalent of the radiating canals of the medusa, the free portion of the tentacles is plainly homologous with the free tentacles, which in the medusa hang from the margin of the umbrella at the points corresponding to the entrance of the radiating into the circular canal, and which must be regarded as strictly the continuation of the radiating canals beyond their apparent termination in the circular canal. The tentacles, which in many medusæ spring from the intervening spaces upon the margin of the umbrella, and are therefore not directly continuous with the radiating canals, make their appearance probably in all cases later than the others, and are frequently less developed. These must be placed in the same category with the lithocysts as simple marginal appendages, to be carefully distinguished from the primary tentacles, and, like the lithocysts, have no representative in the polypite.

* Huxley ('Oceanic Hydrozoa') strongly insists on this relation, and is so impressed with the closeness of the homology, that he uses the same term, "polypite," for both.

Agassiz (*op. cit.* vol. iv. p. 226) has witnessed the very simple adelocodonic gonophore in male specimens of his *Rhizogeton fusiformis*, instead of withering away after the discharge of its contents, elongate itself, develope tentacles, and become transformed into a polypite. I have myself, on one occasion, seen an analogous phenomenon in the female gonophore of *Cordylophora lacustris*, in which, after the discharge of the ova, the spadix had become elongated through the ruptured chitinous investment of the original gonophore, had developed an ectoderm, thrown out tentacles from its summit, and become metamorphosed into an ordinary polypite. In the case of *Cordylophora* the transformation is confined to the spadix, while, according to Agassiz, the entire gonophore of *Rhizogeton* takes part in the metamorphosis.

I believe that in both cases the phenomenon is an abnormal one; it certainly is so in *Cordylophora*, for, in the ordinary conditions to which this hydroid is exposed, no metamorphosis of the kind takes place.

It cannot be urged as an argument against this view, that the circular canal of the medusa is not represented in the polypite; for the absence of a developed umbrella in the polypite necessarily brings with it the absence of this canal; and for the same reason, velum, lithocysts, and secondary tentacles are also absent. Neither can it be said that those cases in which the tentacles of the polypite are not arranged in a single verticil, but are repeated regularly or irregularly in different planes upon the body, are inconsistent with the homological relations here insisted on; for such cases can be regarded only as special modifications of the more typical plan which has directly suggested our comparison.

Huxley, believing the difference in structure and development between the locomotive disc of the gymnophthalmic and that of the steganophthalmic medusæ to be so great as to place them in different categories, would confine the term "umbrella" to the disc of the *steganophthalmata*, and would designate that of the *gymnophthalmata* by the terms "nectocalyx" and "gonocalyx." I was at first disposed to adopt the same view; but an investigation of the mode in which this part makes its appearance in the gymnophthalmic forms has convinced me that the development is essentially the same in both cases, and that, notwithstanding some marked structural differences, there is sufficient unity between the two to render it more convenient to speak of them under the same term as strictly homologous organs. In both cases they are formed by an outgrowth of the walls of the polypoid manubrium, and the fact that the steganophthalmic medusa is produced by successive transverse divisions of a "scyphostoma," while the gymnophthalmic medusa is formed as a lateral bud from a hydroid trophosome, is no valid argument against this approximation; for every segment of the "scyphostoma" is strictly comparable to the bud of the hydroid, and developes its umbrella by an outgrowth from its sides in quite the same way.

A very instructive example, which strikingly bears out the comparison I have here attempted to make between the polypite and the medusa, is afforded by the remarkable locomotive zooid which with its ectotheca forms the gonophore of *Dicoryne* (fig. 4, p. 358). This little zooid is essentially a free medusa, reduced to the condition of an ova-bearing or spermatozoa-bearing manubrium, from whose base two free tentacula are developed. Now there is here no umbrella; but it is evident that we have only to imagine the ectoderm of the manubrium projected as a disc, in the way already supposed, in the horizontal plane passing through the base of the two tentacles so as to include the basal portion of these tentacles in its thickness, in order to have an umbrella with two radiating canals added to the manubrium.

But development entirely coincides with anatomy in pointing to the same conclusion; and it is only necessary to trace the formation of the umbrella and radiating canals in the budding medusa, in order to become convinced that their origin is essentially that here insisted on (see below, p. 397); while the interesting observations of Johannes Müller on the development of *Æginopsis* (see below, p. 418), and of McCrady on that of *Cunina* (see below, p. 419), show that in these genera the umbrella grows out as a horizontal disc from the walls of a free polypoid manubrium, which bears a close resemblance to the generative zooid of *Dicoryne**.

* At the same time, however, we must not, in this comparison, overlook the fact that both *Æginopsis* and *Cunina* belong to the *Æginidæ*, a family which in many respects presents an approach to the *steganophthalmata*; while, according to Fritz Müller's account of the development of *Lyriope catharinensis* (Wiegm. Arch. 1859, p. 310), the process would seem to be, even in the undoubted *gymnophthalmata*, sometimes different; as in this case,

The parallelism which I have thus endeavoured to demonstrate may be expressed in the following scheme.

Phanerocodonic Gonophore.	Adelocodonic Gonophore.	Polypite.
Ectotheca	Ectotheca	0
Umbrella	Mesotheca	Basal web of tentacles in *Laomedea flexuosa*, &c.
Gastrovascular canals	Canals of mesotheca	Base of tentacles extending through the thickness of the body-walls.
Ectoderm of manubrium	Endotheca	Ectoderm of proboscis.
Endoderm of manubrium	Spadix	Endoderm of proboscis.
Manubrium	Spadix + endotheca	Proboscis.
Primary or radial marginal tentacula	Primary tentacula in the meconidium.	Free portion of tentacula.
Secondary or interradial marginal tentacula	Secondary tentacula in the meconidium.	0
Ocelli and lithocysts	0	0
Velum	0	0

D. *Further modifications of the gonosome.*

Besides the great leading differences already described, many others of a more subordinate kind are met with. The adelocodonic gonophore in particular exhibits many special modifications, and presents us with a regular series of gradations in complexity, which throw much light on its morphology.

The simplest form is probably that which we meet with in the female gonophores of the freshwater *Hydra*. Here there would seem to be no differentiation of an ectotheca, while the spadix itself remains in a rudimental condition, being scarcely elevated above the base of the gonophore, whose whole cavity becomes at an early period occupied by the single large spherical ovum.

An advance over this condition is seen in the sexual bud which is borne by that form of medusa described above, under the name of "gonoblastocheme." Here we have the ultimate sexual bud quite destitute of ectotheca, and reduced to the condition of spadix and endotheca separated from one another by the intervening generative elements (fig. 18, p. 401).

In *Clava*, *Hydractinia*, &c., we have a still further advance in complexity. The gonophore has here the form of a simple closed sac, whose axis is occupied by a cylindrical or club-shaped spadix, round which the generative elements are clustered (fig. 6 A). Careful examination, however, will show that the walls of the sac consist of two membranes, an outer or ectotheca and an inner or endotheca. The mesotheca is entirely absent.

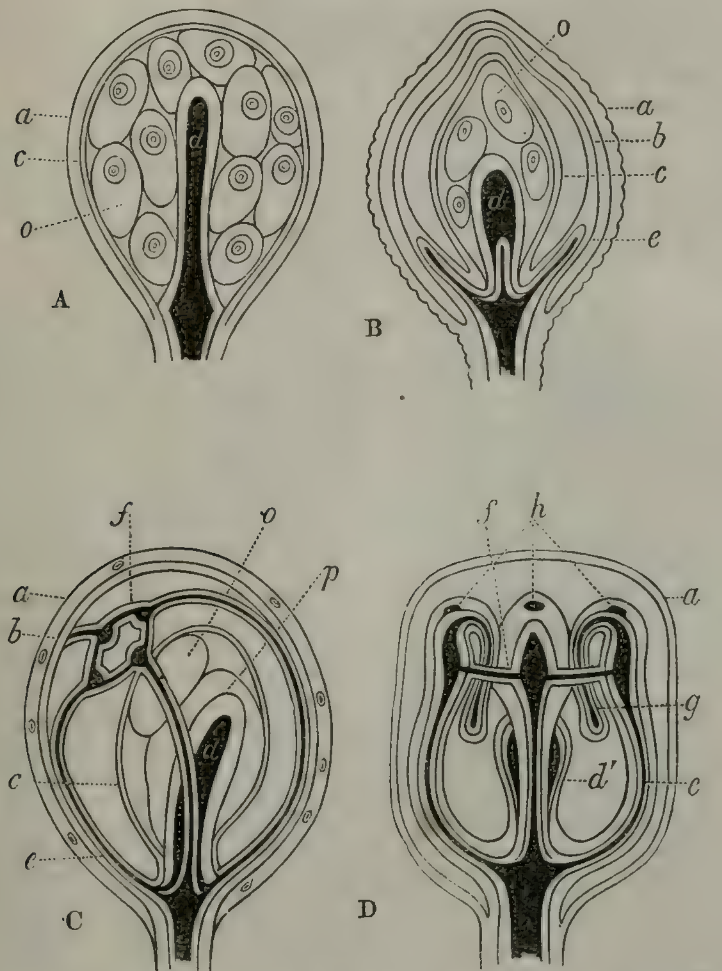
In *Garveia nutans*, Wright, I have found a mesotheca to be distinctly demonstrable; but it is closed at the summit, and destitute of circular canal, while four short radiating canals may be seen in its walls extending from the base of the spadix for about a third of the height of the sac (fig. 6 B).

In *Tubularia indivisa* the mesotheca presents the highest degree of deve-

if the observer has correctly interpreted the appearances, the umbrella would be formed by the excavation of a solid spherical embryo.

lopment which it attains in any adelocodonic gonophore, if we except the peculiar body described below under the name of "meconidium." It is perforated at its summit, and the perforation is surrounded by a distinct circular

Fig. 6.—Types of Gonophores.



A, *Clava multicornis*. B, *Garveia nutans*. C, *Tubularia indivisa*. D, *Syncoryne eximia*.

a, ectotheca; *b*, mesotheca; *c*, endotheca; *d*, spadix; *d′*, manubrium; *e*, radiating gastrovascular canals; *f*, circular gastrovascular canal; *g*, marginal tentacles; *h*, ocelli; *o*, ova; *p*, ovarian plasma in *Tubularia.*

canal which receives four radiating canals, which open into it by small bulbous expansions (fig. 6 C). We thus find almost entirely the condition of a medusa—a medusa, however, which never becomes free, the mesotheca never disengaging itself from the ectotheca, the spadix remaining as a simple cæcal diverticulum, and the codonostome being reduced to a mere perforation of the mesotheca, while this last exhibits but the faintest traces of contractility, and is quite incapable of acting as a locomotive umbrella.

From the sporosac of *Tubularia indivisa* it is thus but a single step to the true phanerocodonic gonophore, such as we find in *Corymorpha nutans*, *Campanularia Johnstoni*, or *Syncoryne* (*Coryne*) *eximia*, where the mesotheca assumes the condition of a contractile locomotive umbrella, with a well-

developed codonostome and velum, and, the manubrium now becoming perforated by a mouth, the gonophore is no longer dependent on the trophosome for its nutrition, but can become free and lead an independent life in the open sea (fig. 6 D and fig. 17).

The typical and ordinary condition of the spadix is that of a hollow cylindrical or clavate body, occupying the axis of the adelocodonic gonophore. Occasionally, however, it departs from this condition and becomes more or less branched, as in *Plumularia pinnata*, *Laomedea caliculata*, &c.

The gastrovascular canals may, as we have already seen, be either entirely suppressed, or present the condition of simple, short, blind tubes, radiating from the base of the gonophore, or be continued from this point as fully developed radiating canals to the distal extremity of the gonophore, where they become united by a circular canal. In *Cordylophora lacustris**, however, instead of being simple tubes, they consist of irregularly branched and anastomosing

* The genus *Cordylophora* was founded by me, in 1843 (Reports of the Meeting of the British Association held in Cork, 1843, and Ann. Nat. Hist. xiii. p. 330), for a remarkable tubularidan with scattered filiform tentacula, a well-developed periderm, and with adelocodonic gonophores scattered upon the ultimate ramuli of its branching trophosome,—a tubularidan, moreover, singularly exceptional in its mode of life, being, with *Hydra*, the only known hydroid which is an inhabitant of fresh water.

Agassiz, in his recent work (Nat. Hist. of the United States, vol. iv. p. 239), refers the genus *Cordylophora* to the genus *Syncoryna* of Ehrenberg, which he reconstructs for this purpose. From such a determination, however, I must altogether dissent. The name *Syncoryna* was introduced by Ehrenberg, in 1832 (Beiträge zur Kenntniss der Corallenthiere des Rothen Meeres), to replace that of *Stipula*, Sars's name for a genus of hydroids exactly equivalent with the *Coryne* of Gärtner, a genus from which *Cordylophora* is absolutely excluded by, among other characters, its filiform tentacula destitute of capitula.

Ehrenberg thinks that a hydroid discovered by Cavolini in the Bay of Naples, and described by him under the name of *Sertularia parasitica* (Mem. Polypi Marini, 1785, pl. vi. figs. 8–13), belongs to the genus *Syncoryna* = *Stipula*. In this, however, he is evidently mistaken, Cavolini's hydroid, so far as we can judge from the account left us by its discoverer, being altogether excluded from the genus *Stipula* as defined and fixed by Sars.

If Ehrenberg had not been, like Sars, led into error as to the just application of the name *Coryne*, he would, instead of changing Sars's name of *Stipula* for one of his own, have simply restored the old name of *Coryne* as originally given by Gärtner.

Agassiz, however, retains the generic name of *Syncoryna*, Ehr., but modifies the genus by removing from it all the forms included in it by Ehrenberg, except the *Sertularia parasitica* of Cavolini, which, as we have just said, was erroneously placed there by Ehrenberg. To this he adds the species of the genus *Cordylophora*, under the belief that *Cordylophora lacustris* and *Sertularia parasitica* are congeneric forms.

Even allowing that this reconstruction of *Syncoryna* in a sense which was not understood by its founder is admissible, I must entirely differ from Agassiz in his generic association of *Cordylophora* with the *Sertularia parasitica*.

The *Sertularia parasitica*, already taken by Van Beneden as the type of a new genus, *Corydendrium*, Van Ben. (Bull. Ac. Brux. 1844), is certainly a very remarkable hydroid, and it is greatly to be desired that we knew something more of it than what is to be gathered from the figures and description (excellent though they be for the time) which have been left us by the celebrated Neapolitan observer. From these, however, so far as they go, we learn that it has a curious complex cœnosarc, consisting in the main stems of fascicles of tubes which become single only in the smaller branches; that it has a singularly extensile and dilatable proboscis; and that, if we be justified in offering any interpretation of the curious buds represented in one of the figures (fig. 11, *c*), we must regard them as phanerocodonic gonophores, for it is impossible not to recognize in them a close resemblance to young medusæ still enclosed in the ectotheca. Of the singular formation of egg-like bodies in the interior of the stems, as described by Cavolini, I cannot offer any explanation.

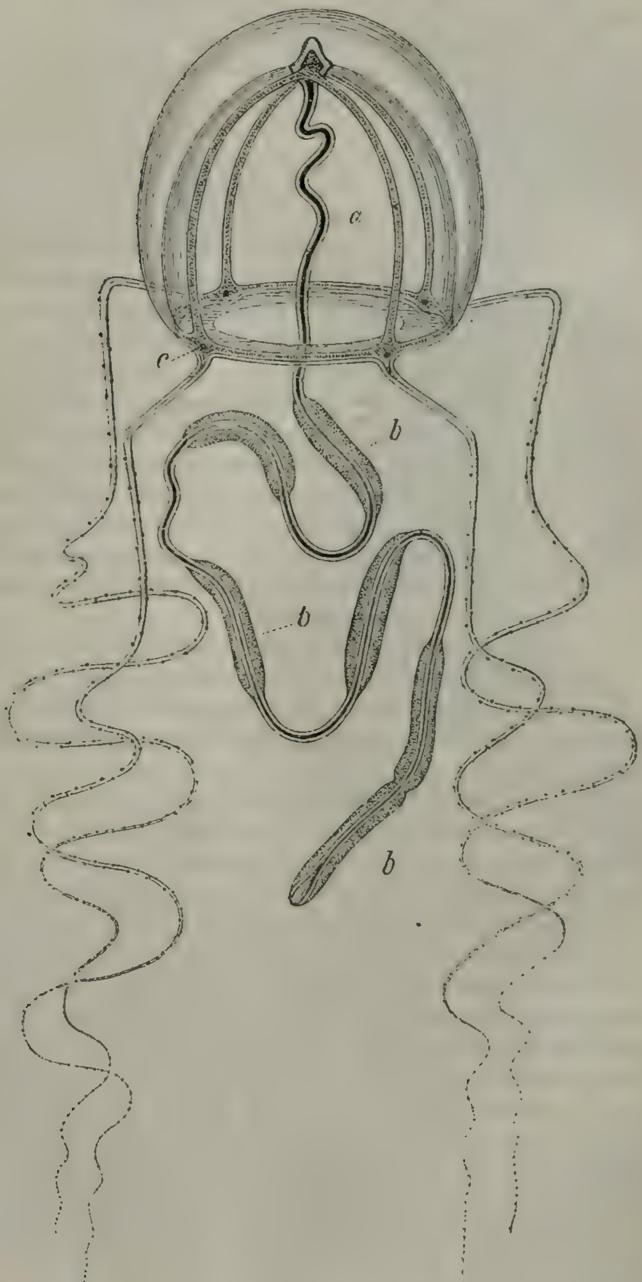
In all these points Cavolini's hydroid stands widely separated from *Cordylophora*, and it cannot therefore be associated with it in a common generic group.

I must therefore continue to maintain the independence of *Cordylophora* as a legitimately constituted genus.

canals which extend from the base to the summit of the gonophore, where they end in blind extremities, without any connexion with a circular canal.

The usual condition of the adelocodonic gonophore is that of a simple, more or less spherical or oval sac. In *Eudendrium*, however, the male gonophores

Fig. 8.—Medusa (*Sarsia strangulata*, Allm., provisionally) of unknown trophosome.



a, very extensile manubrium; *b b b*, male elements developed at intervals between the ectoderm and endoderm of the manubrium; *c*, ocellus.

Fig. 7.

Male gonophore of *Eudendrium*, showing the development of the spermatogenous tissue at intervals between the ectoderm and endoderm.

present the form of a simple sac only at first; for by the time that their contents have approached maturity, new spermatogenous tissue becomes apparent between the endoderm and ectoderm of their supporting peduncles, and these two membranes thus become separated from one another so as to form a second sac immediately behind the first, while a third may in the same way be formed behind the second, the gonophore thus acquiring the peculiar moniliform or polythalamic conformation characteristic of this genus (fig. 7). It will be at once apparent that the separate chambers presented by this peculiar form must not be regarded as so many distinct gonophores; the whole moniliform series ought rather to be viewed as a simple adelocodonic gonophore, in which the endotheca is not uniformly separated from the spadix by the intervention of the spermatogenous tissue, but remains at intervals permanently adherent to it. Among the free medusæ an entirely analogous phenomenon occurs in a *Sarsia*-like medusa of unknown trophosome, which I captured in the towing-net on the south-west coast of Ireland (fig. 8). In this, the manubrium, which is extraordinarily extensile, and can be projected for a great length beyond the umbrella, was enlarged at distinct intervals by the development of the generative elements between its ectoderm and endoderm. The specimen captured was a male, and the manubrium, when extended, presented, by the mode in which the spermatogenous tissue was developed in its walls, five elongated cylindrical enlargements, separated from one another by long thin intervening portions, in which the ectoderm and endoderm of the manubrium continued in direct contact with one another, no generative element being there developed. The spermatogenous mass which occupied the free end of the manubrium was divided into two by a shallow strangulation. The peculiar mode in which the generative elements are developed in the manubrium of *Dipurena*, a nearly allied genus described by McCrady*, would seem to afford an example of an analogous phenomenon.

The gonophore may be borne upon a distinct peduncle, which may be simple (*Syncoryne eximia*, &c.) or branched (*Tubularia indivisa*, *Corymorpha nutans*, &c.), each branch then bearing a gonophore on its summit; or the peduncle may be evanescent, and the gonophore become sessile (*Laomedea flexuosa*, &c.).

The gonophores, whether phanerocodonic or adelocodonic, may be destitute of any further covering, and will then, while attached to the trophosome (*Coryne*, *Clava*, &c.) or to the gonoblastidium (*Dicoryne*, *Hydractinia*, &c.), have their surface in immediate contact with the surrounding water (fig. 2 *c*).

In other cases the gonoblastidium, with its gonophores, may be surrounded by a close case or capsule, formed by a layer of ectoderm with an external chitinous investment (*Campanularia*, *Sertularia*, &c.) (fig. 1 *f*). I have elsewhere designated this capsule by the name of "*gonangium*"†. The gonoblastidium extends through the axis of the gonangium as a cylindrical column, bearing the gonophores as buds upon its sides, and generally expanded at its summit into a conical plug or disc, by which the gonangium is here closed. It will be convenient to distinguish specially this modification of the gonoblastidium; I have elsewhere used for it the term "*blastostyle*"‡, and shall in the present Report employ the same term in the sense thus defined.

In some cases the contents of the gonangium escape, when mature, by the simple rupture of the summit (*Plumularia*, &c.). In others, however, the

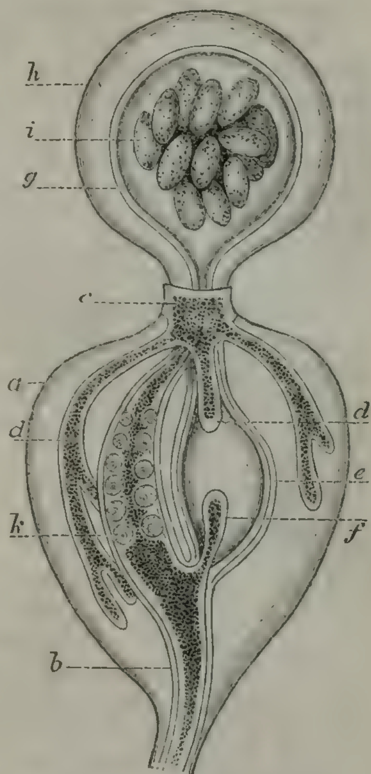
* McCrady, *op. cit.* p. 135.

† Γόνος, and ἀγγεῖον, a vessel. "On the Structure and Terminology of the Reproductive System in the Corynidæ and Sertulariadæ," Ann. Nat. Hist. July 1860.

‡ Βλαστὸς, a bud, and στῦλος, a column. Proc. R. S. Edin. 1858.

summit is separated as a distinct lid, which is then either cast off at once (*Sertularia pumila*, &c.), or it remains moveably attached by one spot of its edge, as by a hinge, to the margin of the aperture thus formed in the summit of the gonangium (*Sertularia operculata*, *Antennularia*).

Fig. 9. — Female gonangium with acrocyst of *Sertularia pumila*.



a, gonangium; *b*, blastostyle; *c*, opercular summit of blastostyle; *d d*, cæcal offsets from the summit of the blastostyle; *e*, gonophore after having discharged its contents into the acrocyst; *f*, spadix; *g*, proper sac of acrocyst; *h*, external gelatinous investment of acrocyst; *i*, ova contained in acrocyst; *k*, young ova in blastostyle.

The Hydroida with naked gonophores may be termed "*gymnogonial*"*, while those in which the gonophores are contained in a gonangium may be termed "*angiogonial*"†.

In by far the greater number of cases the blastostyle carries numerous gonophores, which always increase in maturity as they recede from the base and approach the summit of the gonangium. In some cases, however, the blastostyle bears but a single gonophore; and then it often happens that the gonophore enlarges to such an extent as to fill nearly the entire cavity of the gonangium, the blastostyle being pushed aside out of the axis, and becoming often compressed and flattened over the gonophore, or even becoming partially absorbed, so as to render it difficult to demonstrate its existence‡.

Sometimes the cavity of the blastostyle, though in the very young state quite simple, soon breaks up, from a common point near the base, into several distinct tubes, which again unite in the common cavity of the plug-like summit. This has been shown by Agassiz to be the case in his *Clytia poterium*, and I have myself seen it in a nearly allied, if not identical, species from the east coast of Scotland.

In every adelocodonic gonophore belonging to gymnogonial genera, as well as in most of those which belong to angiogonial genera, the generative elements are discharged directly into the surrounding water, in a more or less developed condition, from the summit of the gonophore. In the females of some angiogonial species, however, the ova, instead of escaping directly from the gonophore into the water, are retained for some time in a

* Γυμνὸς, naked, and γόνος.

† Ἀγγεῖον, a vessel, and γόνος. Since the present Report was laid before the Association, I have seen Victor Carus's "Classification of the Hydroida" in the 'Handbuch der Zoologie,' by Peters, Carus, and Gerstäcker, 1863, and find that he there employs the terms "gymnotoka" and "skenotoka" in the same sense in which gymnogonial and angiogonial are used in the Report.

‡ The difference presented by the gonangia, according as they contain numerous gonophores or only a single one, is regarded by Gegenbaur ('Generationswechsel,' p. 38) as of sufficient importance to induce him to distinguish the gonangia into "polymeric" and "monomeric." I am not disposed, however, to give much weight to this difference, which really consists in a comparatively trivial modification of a common plan.

peculiar receptacle, where they undergo further development, and which is supported upon the summit of the gonangium, and entirely external to its cavity (fig. 9 *g*, *h*). It will be found convenient to employ a special term for this receptacle, which confers upon the gonosomes in which it occurs a very characteristic feature. I have already designated it by the name of "*acrocyst*"*. It may be seen in *Sertularia pumila*, *S. cupressina*, *S. polyzonias*, *Calycella syringa*, &c., and would seem to be in every instance confined to the female.

There is some difficulty in determining the exact morphology of the acrocyst. In its usual form it seems to consist of a simple extension of the endotheca of the gonophore, protruded as a hernia-like sac through the summit of the gonangium, while the whole becomes surrounded by a thick gelatinous-looking envelope, which is excreted from the outer surface of the sac, and which shows no appearance of true structure, though distinct zones of deposition may occasionally be observed in it.

In *Calycella* (*Laomedea*) *lacerata*, Johnst., the spadix itself, as has been correctly stated by Dr. S. Wright, is, with the surrounding endotheca and ova, carried upwards upon the blastostyle, by whose elongation it is protruded as an acrocyst from the summit of the gonangium, when the whole becomes invested by the usual thick gelatinous excretion. The peculiarity of the acrocyst in this case is found in the presence within it of the spadix, which, however, is depressed by the enlarging ova, and forced back into the bottom of the sac.

In the interior of the acrocyst, the ova pass through certain stages of their development, and ultimately escape as free ciliated embryos by the rupture of its walls.

In the cases just described, the acrocyst is destitute of any further covering, and has its walls with their gelatinous investment freely exposed to the surrounding water. In *Sertularia rosacea* and *S. tamarisca*, however, an additional covering is provided for the acrocyst, and there is thus formed a curious and complicated receptacle, in which the ova, as in a sort of marsupium, pass through certain early stages of their development, previously to being discharged into the surrounding water.

The nature and morphology of this receptacle in *Sertularia rosacea* (fig. 10) will be best understood by tracing its development. The young female gonangium is a conical body, with eight slightly projecting longitudinal ridges, and with the broad end of the cone constituting the distal end or summit of the gonangium. A blastostyle occupies its axis, having upon its sides, one over the other, the young budding gonophores, and expanding at its summit into a broad thick disc, which closes, as with a plug, the free end of the gonangium. Upon the outer side of this disc a thin chitinous investment is excreted, becoming continuous at the edge of the disc with the chitinous walls of the gonangium, while in the centre of the disc the chitinous investment is deficient, leaving there a large circular aperture where the summit of the blastostyle is naked.

The edge of the disc soon becomes produced into eight thick symmetrically radiating lobes, which gradually elongate themselves, carrying with them a continuation of the chitinous excretion, which forms a wide tube around each; and now bending upwards, in the form of eight arms with enlarged extremities, they remind one of the disposition of the petals in a flower, and present altogether an appearance of great elegance. These eight radiating arms are composed of ectoderm and endoderm, and have their axis occupied

* Ἄκρον, the summit, and κύστις, a vesicle. Proc. Roy. Soc. Edin. 1858.

by a tubular cavity, which communicates with that of the blastostyle. As the arms continue to elongate, we find them next (h) with their free extremities bending towards one another, until finally, by the meeting of their extremities, they completely enclose an oval space (c), which is entirely shut in by the lateral coalescence of the wide chitinous tubes with which the radiating processes are each invested.

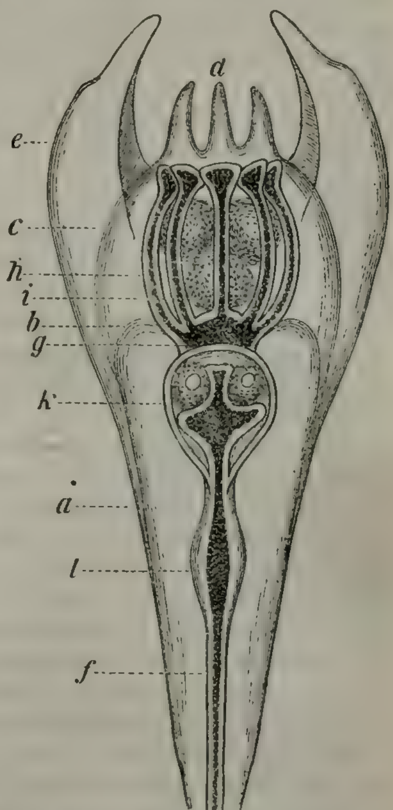
In the mean time the eight longitudinal ribs of the gonangium continue themselves upon the radiating arms, and ultimately extend beyond their extremities as free pointed processes. Two of them, however, situated opposite to one another, greatly surpass the others in size, and mainly contribute to the peculiar and characteristic form of the gonangium*.

If we compare the structure now described with an ordinary polypite, we shall have no difficulty in recognizing an exact parallelism; for the eight tubular processes which are developed from the summit of the blastostyle may be regarded as homologous with the tentacles of a polypite. They have, however, undergone a special modification, by which they become subservient to an entirely different function from that of the tentacles of the polypite; for, no mouth being developed on the blastostyle, they are no longer prehensile organs administering to the alimentation of the colony, but, like the blastostyle itself, have assigned to them functions appertaining to reproduction rather than nutrition, and are destined to circumscribe a cavity for the retention and development of the ova.

The ova would seem to continue in the marsupial cavity until they have acquired the condition of ciliated embryos.

The modification of marsupial receptacle which occurs in *Sertularia tamarisca* is also very interesting. The female gonangia (fig. 11) are here of an oval form for about the proximal half of their length, and then become trihedral, with the sides diverging upwards, while the whole is terminated by a three-sided pyramid. The sides of the pyramid are cut into two or three short teeth along their edges, and each of their basal angles is prolonged into a short spine.

Fig. 10.—Female gonangium with marsupial chamber of *Sertularia rosacea.*



a, lateral walls and, b, roof of the gonangium proper; c, chitinous walls of the marsupial chamber; d, three of the six smaller and, e, the two larger spine-like processes which crown the marsupial chamber; f, blastostyle; g, disc-like summit of the blastostyle; h, the eight radiating tubular processes from the summit of the blastostyle; i, ova in the marsupial chamber, the germinal vesicle having already disappeared; k, gonophore still attached to the blastostyle, and containing two ova with the germinal vesicle distinct; l, dilatation of the blastostyle, probably an incipient gonophore.

* In *Sertularia fallax* also a marsupial chamber is developed in the gonangium, and, judging from the figures and short description given by Dr. Strethill Wright (Proc. R. Phys. Soc. Edin. 28th April, 1858), it would seem that the structure is very nearly identical with that here described in *S. rosacea.*

The trihedral portion, with its pyramidal summit, is formed of three leaflets (*b*), which merely touch one another by their edges without adhering, so that they may be easily separated by the dissecting-needle or by the embryo during its escape. They consist of the same chitinous material as that which forms the rest of the gonangium, excreted doubtless originally upon the surface of an ectodermal lamina.

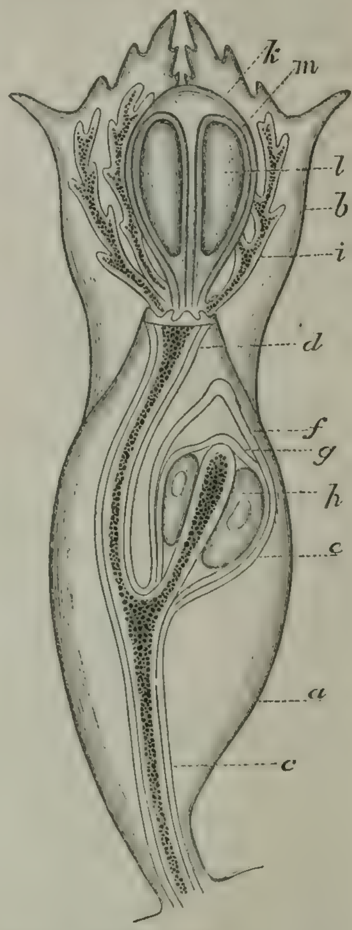
On laying open the gonangium, the oval or proximal portion of it is seen to be occupied by a blastostyle (*c*, *d*), which gives origin to one or more gonophores (*e*). It terminates upwards by closing round the distal extremity of the blastostyle, where it forms a ring, with tooth-like processes, by which the extremity of the blastostyle is encircled. This oval portion constitutes the gonangium proper, and is the only part developed in the male.

From the summit of the blastostyle several irregularly branched cæcal tubes (*i*), apparently communicating with its cavity, are given off; they lie altogether external to the oval portion or gonangium proper, and embrace a delicate sac (*k*), within which are one or two ova (*l*) in an advanced stage of development, each in a delicate structureless sac (*m*) of its own, which is continued by a narrow neck to the summit of the blastostyle.

The ova, with their investing sacs and the surrounding cæcal tubes, are further closed in by the three leaflets already mentioned as constituting the trihedral portion of the gonangium. These leaflets are given off from the sides of the oval portion, or proper gonangium, a little below its summit; and, being in contact by their edges, completely enclose a space which is occupied by the structures just described.

The homological relations between the marsupial receptacles of *Sertularia rosacea* and *S. tamarisca* are at once apparent, and are very interesting. The ramified tubes (fig. 11 *i*) of *S. tamarisca* are manifestly the representatives of the eight simple tubes (fig. 10 *h*) in *S. rosacea*, while the three broad chitinous leaflets which surround the whole externally are homologous with the continuation of the gonangium in *S. rosacea*, where, with its prominent ridges and spines, it forms an external capsule-like covering for the sac into which, as in *S. tamarisca*, the ova are expelled from the gonangium proper.

Fig. 11.—Female gonangium with marsupial chamber of *Sertularia tamarisca.*



a, lateral walls of the gonangium proper; *b*, two of the three chitinous leaflets which form the outer walls of the trihedral marsupial chamber; *c*, blastostyle; *d*, opercular summit of blastostyle; *e*, gonophore budding from the blastostyle; *f*, its ectotheca; *g*, its endotheca; *h*, ova; *i*, ramified cæcal processes from the summit of the blastostyle; *k*, delicate membranous sac, forming the inner walls of the marsupial chamber; *l*, ova contained within this sac; the germinal vesicle has disappeared, and they have nearly acquired the condition of planulæ; *m*, delicate special sac of the ovum.

The structures just described in *Sertularia rosacea* and *S. tamarisca* will, I think, enable us to explain a peculiar feature observed in *S. pumila* and probably some other species. In *S. pumila* the blastostyle of both male and female gonangia gives off from its enlarged opercular summit several more or less ramified cæcal tubular processes (fig. 9 *d*), which, instead of developing themselves externally, are found entirely within the gonangium, where they hang freely from the summit of the blastostyle. Their walls are composed both of endoderm and ectoderm, and their cavity communicates with that of the blastostyle, so that the peculiar coloured corpuscles which circulate within the cavity of the blastostyle are freely admitted into the cæcal tubes, where they may occasionally be seen in active motion. The tubes can be most satisfactorily examined in the younger gonangia. In the older ones they will frequently be found to have contracted adhesions to the gonangium, to have become atrophied, and, finally, even to have disappeared.

I believe that these tubes are the exact equivalents of those which in *Sertularia tamarisca* and *S. rosacea* are given off from the same part of the blastostyle, but where, instead of growing into the cavity of the gonangium, they are developed in an outward direction, and assist in the formation of the peculiar receptacle which surrounds the acrocyst in those species*.

Among the various modifications presented by the gonosome there is perhaps not one more interesting than that which we meet with in *Laomedea Lovéni*, Allm., and at least one other allied species. In this hydroid there are borne upon the summit of the gonangium, and altogether external to its cavity, certain very peculiar gonophores, which convey the impression of small, fixed, imperfectly developed medusæ (fig. 12 *g g*). It was to these extracapsular gonophores that Lovén long ago† called attention when he supported and developed the doctrine, just then announced by Ehrenberg, of the sexuality of the HYDROIDA—a doctrine which, though in its mode of statement not absolutely correct, was yet full of significance.

The bodies in question are nearly spherical sacs, and occur in both the male and female colonies. In their walls may be demonstrated an ectotheca, mesotheca, and endotheca. The generative elements (*m*) are formed within the endotheca, and surround a well-developed spadix. The endotheca, however, is generally of short duration, becoming absorbed or ruptured under the increasing volume of its contents. In the female four very distinct radiating canals (*l*) may frequently be seen; these spring from the base of the spadix, and thence run in the walls of the mesotheca towards the opposite end of the sac. In many cases, however, I was unable to detect any trace of these canals, and could never find them in the male. We should, however, be scarcely justified in asserting that in such cases they are altogether absent; for it is quite possible that emptiness or some other peculiar condition at the time of observation may have caused them to escape detection—a sup-

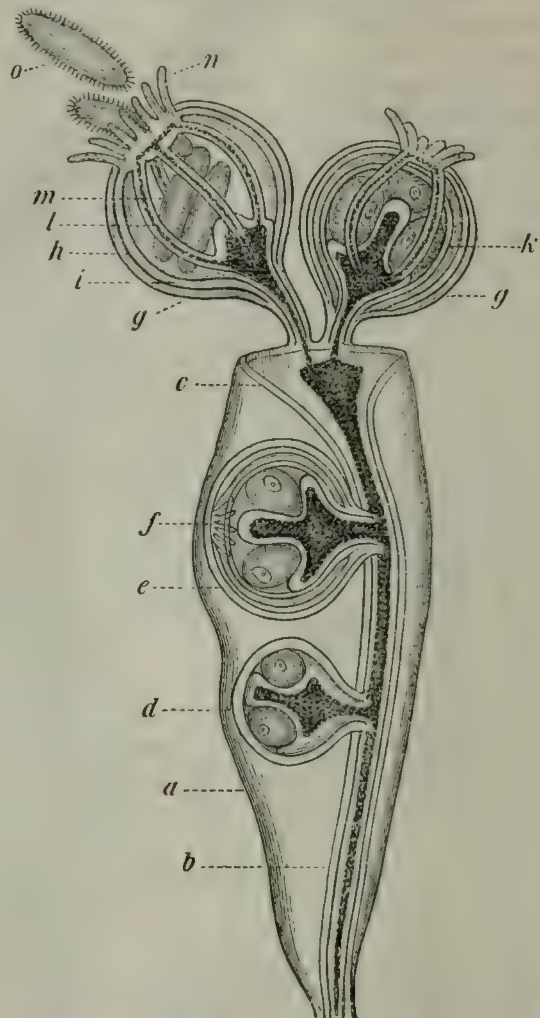
* It is evidently the tubes here described to which Agassiz (Nat. Hist. U. S. vol. iv. p. 329. pl. xxxii. figs. 10, 10ª) refers as occurring in a North American hydroid which he regards as identical with the *Sertularia pumila* of the European coasts. He views them, however, as simply representing the fleshy bands which may frequently be seen in the trophosome of the Hydroida, extending from the outer surface of the cœnosarc to the inner surface of the chitinous periderm, and which these tubes certainly resemble when they become more or less atrophied and adherent to the walls of the gonangium. They are also described and figured by Lindström in a paper on the development of *Sertularia pumila* (Oefversigt af Köngl. Vetenskaps-Akademiens Förhandlingar, 1855.)

† Lovén, Beiträge zur Kenntniss der Gattungen *Campanularia* und *Syncoryne*, Wiegm. Arch. 1837. Lovén names the hydroid in which he witnessed the extracapsular gonophores *Campanularia geniculata*, which is certainly a wrong determination of the species.

position which receives confirmation from the fact that, even in those cases where they are most obvious, they become obliterated under slight pressure.

At the summit of the sac the mesotheca is perforated by a circular aperture, round which its walls appear to be thickened, and probably contain here a rudimental circular canal in which the radiating canals terminate; at least, the presence of coloured granules at this spot affords an indication of the existence of such a canal. The ectotheca, which is loaded with thread-cells, is also perforated by an aperture corresponding to that of the mesotheca; and the gonophore is crowned by a circle of short tentacles (*n*), which seem to originate from the thickened margin of the perforation in the summit of the mesotheca.

Fig. 12.—Female gonangium with meconidia of *Gonothyræa* (*Laomedea*) *Loveni*.



a, chitinous walls of the gonangium; *b*, blastostyle; *c*, opercular summit of blastostyle; *d*, young gonophore in the cavity of the gonangium; *e*, more mature gonophore, still in the cavity of the gonangium; *f*, its tentacles turned back on the sides of the mesotheca; *g g*, meconidia; *h*, ectotheca, *i*, mesotheca, and *k*, endotheca of meconidium; *l*, radiating canals; *m*, ova become planulæ in the more mature meconidium; *n*, tentacles of meconidium; *o*, ciliated planula just escaped from meconidium.

The tentacles possess, like the marginal tentacles of a true medusa, considerable contractility. They may frequently be seen of very different lengths in different gonophores of the same colony; and this, which is really the result of different degrees of contraction, may be easily taken for different degrees of development, the tentacles being especially sluggish in the acts of extension and contraction. Their length, when fully extended in the female gonophore, will equal about half the diameter of the gonophore: while under external irritation, they will slowly contract to a third of their original length, and will then show themselves as a little stellate crown on the summit of the gonophore. They vary in number: I have counted in the female from 8 to 16 or 20. They are composed of ectoderm and endoderm, the ectoderm containing thread-cells, and the endoderm presenting the usual septate appearance. They are less numerous and less developed in the male than in the female.

The contents of the gonophore are either ova or spermatozoa, and the sexes are invariably found separated on distinct colonies. The ova, while contained within the gonophore, pass through the various stages of development up to that of ciliated embryos, in which state, as has been already shown by Lovén, they are discharged into the surrounding water through the orifice in the summit.

If we follow the development of these extracapsular gonophores, we shall find (*d*, *e*), as indeed Lovén had already pointed out, that they are originally produced within the gonangium where they originate, exactly like ordinary intracapsular gonophores, as buds from the blastostyle. By the growth of the blastostyle the gonophores are carried upwards with it, in the order of their maturity,—the oldest ones, while within the gonangium, being always nearest the summit of the blastostyle; but instead of discharging their contents and then withering away on their arrival at the summit of the gonangium, as in ordinary adelocodonic forms, they are here carried out through the summit, become truly extracapsular, and in this state undergo, with their contents, further development, while the growing blastostyle always keeps its extremity truncated on a level with the gonangium, whose orifice it continues to close by a plug-like expansion, which at the same time affords a support for the gonophores after they have become extracapsular. Two or three of these extracapsular gonophores, in different stages of development, may be usually seen, borne each by a short peduncle upon the opercular summit of the blastostyle, with whose cavity that of their spadix freely communicates through the tubular axis of the peduncle.

While the gonophore is still contained within the gonangium, the mesotheca has become developed in it, and the rudimental tentacles (*f*) may be seen thrown back upon its walls in the form of a little star, while the whole is confined in the investing ectotheca.

That the bodies now described belong to the class of adelocodonic rather than to that of phanerocodonic gonophores must, I think, be admitted. In all essential points, except in the presence of tentacles developed from the mesotheca, they agree with the gonophores of *Tubularia indivisa*, which must certainly be classed among the adelocodonic forms, notwithstanding their possession of a well-developed mesotheca and gastrovascular canals. In both the aperture of the mesotheca is reduced to a mere perforation, and in neither is the mesotheca ever developed as a locomotive organ.

It must also be borne in mind, that when true phanerocodonic gonophores are produced in *Laomedea* and other *Campanularidæ*, they belong in almost every instance to the type in which the generative elements are not produced directly, as in this case, between the ectoderm and endoderm of the manubrium, but are formed in special zooids developed from some part of the gastrovascular system; *Laomedea tenuis*, Allm.*, and, according to an observation of A. Agassiz †, *Lafœa cornuta*, Lamx., affording the only known exceptions to this rule.

The extracapsular gonophores of *Laomedea Lovéni* are thus of no little interest in the morphology of the Hydroida, and it will be found convenient to speak of them under a special name. Their resemblance to a pomegranate, or perhaps still more obviously to a poppy-capsule, with its sessile stellate stigma, will instantly strike us; and it is this comparison which has suggested to me the name of "*meconidium*" ‡, by which I have elsewhere found it useful to designate them.

* "Notes on the Hydroid Zoophytes," Ann. Nat. Hist., Nov. 1859. † Agass. *op. cit.* p. 351.

‡ A diminutive noun, formed from μήκων, a poppy. "Notes on the Hydroid Zoophytes," Ann. Nat. Hist., August 1859.

A very remarkable feature, which one is at first sight tempted to place in the same category with the formation of meconidia, but which is in reality of an entirely different significance, is presented by *Halecium halecinum*. In this hydroid there is borne upon the summit of the female gonangium, in a situation precisely similar to that of the meconidia of *Laomedea Lovéni*, a pair of polype-like bodies. These bodies present no appreciable difference by which they may be distinguished from the ordinary polypites of the trophosome. They are of an elongated oval form, with the mouth situated on the summit of a short conical proboscis, which is surrounded by a circle of about twenty-one filiform tentacula. They are always two in number, and diverge from a common point of attachment, while their wide gastric cavities, after contracting below, communicate here with one another and with the tubular cavity of the blastostyle.

I have never been able to discover any direct relation between these gonangial polypites and the generative functions of the hydroid. The blastostyle gives origin in the usual way, within the cavity of the gonangium, to a gonophore, which, so far as I have observed, is always single. This gonophore never becomes extracapsular; and the ova, after being discharged from it by the rupture of its walls, finally escape through the summit of the gonangium, probably after the disappearance of the gonangial polypites.

I may here mention a very singular body, whose exact significance I have never been able satisfactorily to determine, and which may be seen in the female gonangium of *Antennularia antennina*, where it is of frequent occurrence. It is always found floating free in the cavity of the gonangium, along with the ova which have escaped from the ruptured gonophores, and resembles an imperfectly developed medusa, with a large and apparently imperforate manubrium, but with its umbrella closed, and without any trace of gastrovascular canals. The walls of the umbrella are separated from the central manubrium by a considerable space, which is filled with a clear fluid. It may be compared to a free sporosac; but it is much smaller than the ordinary sporosacs of the *Antennularia*; and I have never observed in it any trace of generative elements. It is probably produced, like the true gonophores, as a bud from the blastostyle; but I can offer no decided opinion either as to its origin or its ultimate destination. Its whole structure precludes the idea of its being an accidental parasite.

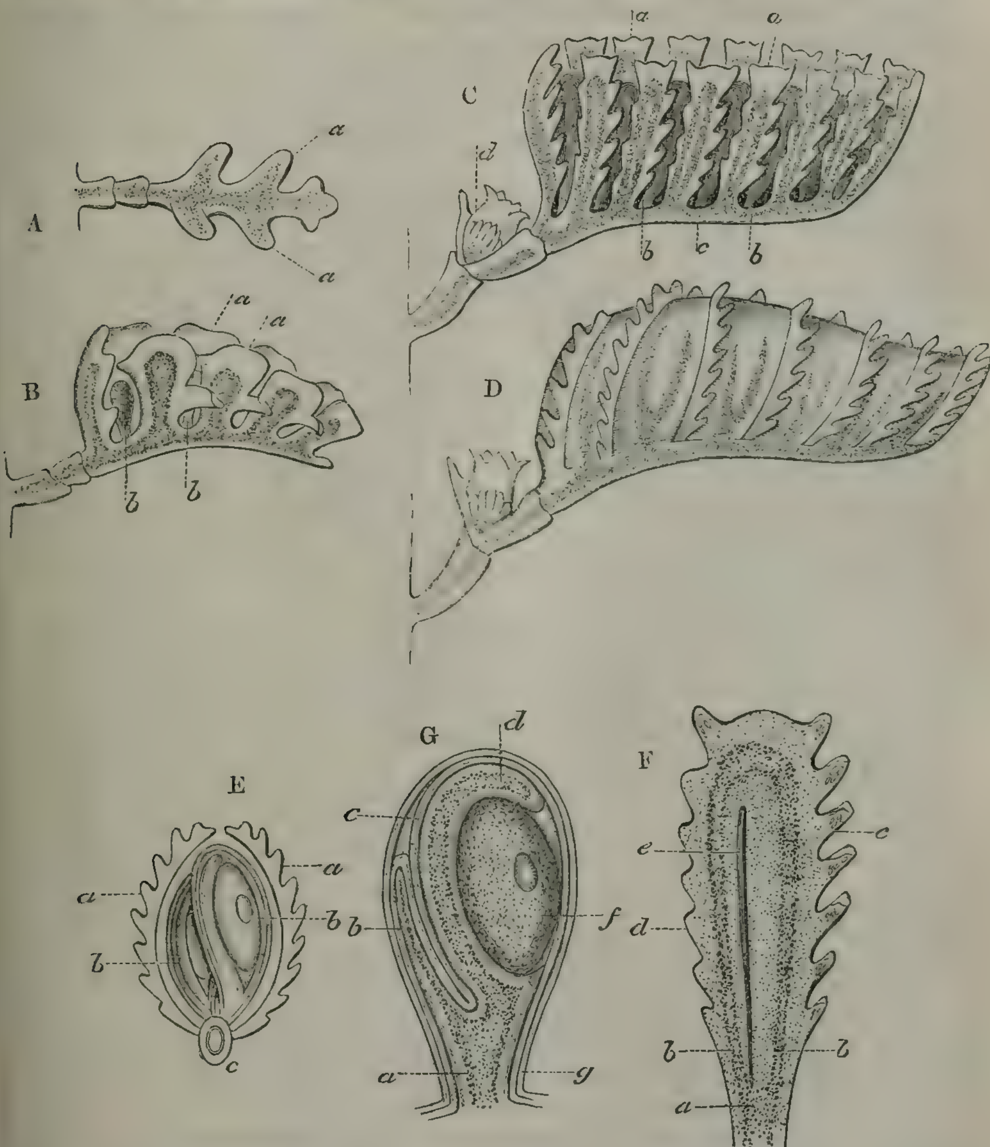
In almost every case the gonangium, when present in the Hydroida, is destitute of any further covering. In certain species, however, belonging to the genus *Plumularia* and its allies, the gonangia are developed in groups, and each group is contained in a common receptacle, which confers upon the hydroid in which it exists a very striking and characteristic feature. This receptacle must be carefully distinguished from a proper gonangium, with which indeed it has been confounded in the various descriptive works on the HYDROIDA. It will therefore be very convenient to give it a special name, and I have already proposed for it the term *corbula**, suggested by its basket-like form.

I have carefully studied the nature of the corbulæ in *Aglaophenia pluma* (fig. 13) (the *Plumularia cristata* of most authors), where they may be plainly seen to be metamorphosed ramuli. The peculiar metamorphosis of a ramulus, which results in the formation of a corbula, consists in the suppression of the hydrothecæ, accompanied by the development on each side of the ramulus of numerous oval, hollow, alternately placed leaflets; each leaflet consisting of a diverticulum from the cœnosarc of the ramulus, invested with a continuation of the general periderm.

* *Corbula*, a basket. Proc. Roy. Soc. Edin. 1858.

In the earliest stages of these leaflets their edges are entire (A *a*), but they soon become deeply serrated by the formation of hollow tooth-like processes (F *c*) upon the edge which is turned towards the distal extremity of the ra-

Fig. 13.—Development of the Corbula in *Plumularia* (*Aglaophenia*) *pluma*.



A, very young corbula; B, corbula more advanced; C, corbula in a still more advanced stage; D, the mature corbula; E, transverse section of mature corbula, showing two gonangia, each containing a single gonophore. *a*, leaflets of corbula; *b*, gonangia; *c*, ramulus supporting the leaflets; *d*, a hydrotheca.

F, separate leaflet from mature corbula. *a*, continuation of the somatic cavity into the leaflet, where it divides into two branches, *b b*; *c*, nematophores forming tooth-like processes on the distal edge of the leaflet; *d*, imperfectly developed tooth-like processes on the proximal edge; *e*, septum dividing the cavity of the leaflet.

G, gonangium from mature corbula. *a*, continuation of somatic cavity into gonangium; *b*, blastostyle, partially suppressed by the enlarging gonophore; *c*, gonophore; *d*, spadix; *f*, ovum; *g*, wall of gonangium.

mulus. Upon the proximal edge of the leaflet these processes usually remain in an imperfectly developed state, though they are occasionally equally well developed on both edges. The processes which are thus developed on the edges of the leaflet are in all respects similar to the lateral nematophores of the trophosome (see above, p. 355). They are filled, like these, with soft granular protoplasm, in which is immersed a cluster of fusiform thread-cells, and which is in direct communication with the cœnosarc filling the cavity of the leaflet. They are also, like these, perforated at their extremity by an oblique aperture; but I have never seen the nematophores of the corbulæ emit, like those of the trophosome, pseudopodial prolongations of their contents.

The leaflets, as they increase in size, direct themselves vertically from the upper surface of the ramulus, and those of one side arch over so as to approach those of the opposite. They are at first free, but they afterwards become intimately united at their edges, the nematophores continuing to project as tooth-like processes, and forming an elegant serrated ridge between every two leaflets. Ultimately the leaflets of one side coalesce with those of the other by their summits, and thus form a completely closed chamber (D).

As the young leaflet continues to grow, its cavity becomes partially divided by a septum (F *e*), which stretches across from the outer to the inner side, parallel to the axis of the leaflet, but always nearer to the proximal edge. At the free end of the leaflet the septum is incomplete; so that here the contents of the cavity at one side of the septum communicate with those upon the other side, both sides communicating at the base of the leaflet with the common cavity of the cœnosarc.

In the receptacle thus formed the gonangia are produced. They spring from the upper side of the metamorphosed ramulus, near the point where the leaflet leaves it, and represent the hydrothecæ which exist on an ordinary ramulus, and whose place they here take. They begin to be produced at an early stage of the corbula, and may be easily examined in the young corbula before it has become closed (B *b*, C *b*). The metamorphosed ramulus generally remains unchanged for a short distance from its origin, and may be here seen bearing one or two ordinary hydrothecæ.

About twelve gonangia are usually contained in each corbula. They are of a very simple type (G), of a regular oviform figure, and with their chitinous walls thin and delicate. Each gonangium seems to contain but a single sporosac, which soon comes to occupy almost the whole cavity of the gonangium. A long, nearly cylindrical spadix extends almost from the base to the summit of the sporosac, passing in the male through the axis of the mass of spermatogenous tissue, but in the female pushed to one side by the development of the large single ovum, which here occupies almost the whole remaining portion of the cavity of the sporosac.

There may appear some difficulty in deciding as to whether the corbula ought to be regarded as properly belonging to the trophosome or to the gonosome. The truth is, that it holds a place exactly intermediate between the two, and may in this respect be compared to the bracts in plants; for these are in the same way intermediate between the ordinary leaves and the proper floral verticils. As the bracts, however, are usually treated of in connexion with the *inflorescence*, whose limitation they frequently determine, we shall perhaps here also find it convenient to speak of the corbula in connexion with the gonosome rather than with the trophosome*.

* In a very ingenious paper, "On the Morphology of the Reproductive System in the Sertularian Zoophytes," by Prof. E. Forbes (Ann. of Nat. Hist. 1844, vol. xiv. p. 385),

I have thus far endeavoured to give a complete account of the morphology of those portions of the hydroid which are destined for the origination and protection of the generative elements; but, before passing to the consideration of these elements themselves, it may be well to inquire whether there is any general rule as to the distribution of the adelocodonic and phanerocodonic gonophores, and of the two forms of the latter among the several families of the HYDROIDA.

There is no established instance of the same species of hydroid producing both phanerocodonic and adelocodonic gonophores either simultaneously or consecutively. Sars is certainly in error when he includes under his *Podocoryne carnea* two forms of hydroids, one with developed medusæ, and the other with sporosacs *; and there can be little doubt that Van Beneden has made some confusion between two distinct species when he figures a portion of a hydroid colony, which he names *Campanularia geniculata*, with two kinds of gonangia, one containing medusæ, and the other sporosacs †.

The *Tubularida* present examples of both phanerocodonic and adelocodonic gonophores, which are borne either by the trophosome directly or by gonoblastidia; but, so far as our present knowledge extends, the instances of adelocodonic gonophores are rather more numerous among the *Tubularida* than those of phanerocodonic gonophores. The phanerocodonic gonophores of the *Tubularida* belong, so far as we yet know, exclusively to the type described above under the name of gonocheme, the generative elements not being here proved ever to originate in special buds upon the course of the radiating canals. I regard it, however, as highly probable that the sexual lobes of *Nemopsis*, whose bases extend over portions both of the manubrium and radiating canals, will prove to be true zooids. The trophosome of *Nemopsis* has been shown by M^cCrady to be a free Tubularian polypite; and if the zooidal nature of the sexual lobes be proved, we shall have among the *Tubularida* an exceptional condition which may be compared to that presented by *Laomedea tenuis* among the Campanularians ‡.

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the author recognizes in the corbulæ of *Aglaophenia pluma*, and some other allied species, their true significance as metamorphosed branches. He mistakes, however, the nature of the metamorphosis, while, in accordance with the prevailing view, he sees in the receptacles in question bodies in all respects corresponding to the proper gonangia of the other hydroids.

Forbes, moreover, extends his generalization, applying it to the gonangia of the other Sertularians, which he believes must be all regarded as peculiarly metamorphosed branches, with metamorphosed and confluent hydrothecæ, exactly in the same way that the floral verticils in plants may be referred to verticillate, metamorphosed, and variously combined leaves. "The vesicle," he says, "is formed from a branch or pinna through an arrest of individual development, by a shortening of the spiral axis, and, by a transformation of the stomachs (individuals) into an ovigerous placenta, the dermato-skeletons (or cells) uniting to form a protecting capsule or germen; which metamorphosis is exactly comparable with that which occurs in the reproductive organs of flowering plants, in which the floral bud (normally a branch clothed with spirally arranged leaves) is constituted through the contraction of the axis and the whorling of the (individual) appendages borne on that axis, and by their transformation into the several parts of the flower (reproductive organs)."

The theory, however, involved in the above statement, attractive though it be, is contradicted by the actual development of the parts in question. When Forbes wrote, so little was known of the structure and development of the HYDROIDA, that this accomplished and lamented naturalist may well be excused if some parts of his very suggestive paper have refused to stand the test of subsequent research.

* Sars, Faun. Lit. Norv. p. 7. pl. 2. fig. 5.

† Van Beneden, Mém. sur les Campanulaires, pl. 3. figs. 1–6.

‡ Agassiz describes (Cont. to the Nat. Hist. of the United States, vol. iv. p. 281) the medusa of his *Pennaria gibbosa* as presenting slight fusiform enlargements of the radiating canals, which he is disposed to regard (though not without doubt) as rudimental generative

Among the Campanularians we also meet with many examples of free medusa-buds, as well as of fixed sporosacs, the free medusæ being, so far as we yet know, rather more frequent than the sporosacs. They are both borne as buds upon the blastostyle of a gonangium; but the free medusæ are (with two known exceptions, those, namely, which are afforded by *Laomedea tenuis*, mihi, and *Lafœa cornuta*, Lamx.) always gonoblastochemes, the generative elements being produced in special sexual buds which arise from some part of the radiating canals.

Finally, among the Sertularians we know as yet of no instance of a free medusa, the generative elements being among these hydroids always produced in adelocodonic gonophores which, as in the Campanularians, are invariably borne upon the blastostyle of a gonangium*.

III. Structure and Formation of the Generative Elements.

The existence of generative elements—ova and spermatozoa—has now been fully determined in every important group of the Hydroida.

Ova.—The hydroid ovum (fig. 20 A), in all those cases where its structure has been satisfactorily seen, consists of a granular vitellus enveloping (except alone in the genus *Tubularia*) a distinct more or less excentric germinal vesicle, in which one or more germinal spots may be almost always demonstrated, and occasionally with one or more nucleoli in the interior of the germinal spot. The whole is invested by an exceedingly delicate vitellary membrane, which, though it sometimes escapes detection, is probably always present, at least in the young ovum. In the genus *Tubularia* alone the most careful investigation has as yet failed in detecting any trace of germinal vesicle or spot.

In the earliest stage in which I have in any case succeeded in observing the ova, that namely presented by these bodies in the young gonophore of *Coryne pusilla*, I have found nothing but minute, clear, nucleated vesicles immersed in a common granular plasma. That these are to constitute the germinal vesicle and spot of the more mature ovum seems certain, while the granular plasma in which they are immersed would appear to represent the vitellus, though I could as yet trace no differentiation in it indicating a separation into distinct masses accumulated round the individual germinal vesicles. In a more mature stage, however, each vesicle had its own specialized vitellus surrounded by a distinct vitellary membrane.

Spermatozoa.—The spermatozoa possess the form which so generally characterizes those bodies throughout the animal kingdom, being here in all cases active caudate corpuscles (fig. 14 D *d*). The caudal filament is sometimes of such extreme tenuity as to render it very difficult of detection,

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sacs, while he has never observed generative elements in the manubrium. I feel convinced that the doubts of Agassiz on this point are even better founded than he himself will admit, and that the structures alluded to have nothing to do with generative sacs; while the analogy of closely allied species (see Cavolini, Mem. Polypi Marini; McCrady, Gymnophthalmia of Charleston Harbour) renders it almost certain that *Pennaria gibbosa* affords no exception to the general rule, that the free medusæ of the *Tubularida* never develope generative buds upon the course of the radiating canals.

* Agassiz (*op. cit.* vol. iii. pp. 46 & 48), referring to a Sertularian which he names *Dynamena Fabricii*, and calls one of the most common Sertularians of the Atlantic coast of North America, asserts that this hydroid produces free medusæ, of which he gives figures. There is probably some mistake here; the fact is mentioned only in a casual way; and in the following volume, in which a detailed account of the North American species of Hydroida is given, no allusion is made to it, though the closely allied, if not identical, *Dynamena* (*Sertularia*) *pumila* is minutely described.

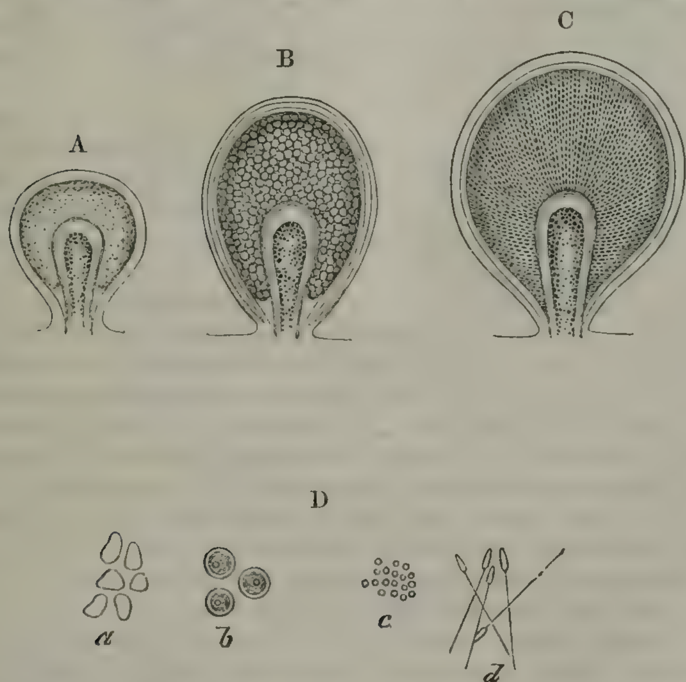
while the head varies in form, being usually conical—and then with the filament attached to the wide end of the cone,—but sometimes spherical, or cylindrical, or "guitar-shaped"*, according to the species.

The spermatozoa seem to be always developed in true sperm-cells which are themselves frequently contained as a brood in the interior of mother cells, as may be very well seen in *Sertularia polyzonias*, where the cells which give immediate origin to the spermatozoa form groups of from two to four enclosed within a common mother cell. The spermatozoon itself seems due to the metamorphosis of the nucleus of the sperm-cell.

In *Laomedea flexuosa* I have carefully followed the progress of the spermatogenous tissue from a very early period to the formation of the mature spermatozoon. In the very young gonophore (fig. 14 A) the spadix may be here seen surrounded by a nearly transparent mass, which is destined to become developed into spermatozoa, but which presents as yet no obvious structure beyond a minutely granular condition, which under the action of acetic acid becomes more distinct.

In a stage a little further advanced (B) the gonophore has increased in size, and the spermatogenous mass has become more voluminous and has acquired

Fig. 14.—Development of the spermatozoa in *Laomedea flexuosa.*



A, very young male gonophore bud, with the spermatogenous plasma interposed between the ectoderm and endoderm; B, gonophore further advanced; C, mature gonophore; D, structure of spermatic tissue at various stages. *a*, spermatic tissue from B; *b*, the same, after having been treated with acetic acid; *c*, spermatic tissue from a gonophore somewhat further advanced than B; *d*, mature spermatozoa from C.

a manifest structure, being now plainly formed by a peculiar tissue which, when liberated from the confinement of the gonophore and spread over the

* The spermatozoa of *Eudendrium dispar*, Agassiz, and some other species are so described by Agassiz in Nat. Hist. of the United States, vol. iv.

field of the microscope, is seen to consist of a multitude of bodies of a rather irregularly pyriform or conical shape, and about $\frac{1}{3000}$th of an inch in diameter (D *a*). These bodies, when set free, present for the most part an evident vibratory movement, which is plainly a vital phenomenon, and distinct from mere molecular motion, though as yet no filament or other source of the motion can be detected. When treated with acetic acid, they assume a regularly spherical form, and have then all the appearance of thick-walled cells with an undoubted nucleus in their interior (D *b*).

In a more advanced stage the contents of the gonophore have still further increased in opacity, and are now seen to be entirely composed of very minute spherical corpuscles (D *c*) about $\frac{1}{9000}$th of an inch in diameter, and presenting a close resemblance to the nuclei of the cells composing the spermatogenous tissue in the stage last described. They exhibit distinct but not active motion under the microscope, though no filament can as yet be demonstrated in them.

In the next stage (C) the gonophore has attained maturity, and the spermatogenous mass has become still more opake than in the preceding stage, and presents a peculiar striated appearance, the striæ radiating from the sides of the spadix to the walls of the gonophore. Soon after the gonophore has attained this condition it bursts, and allows its contents to escape into the surrounding water as mature active spermatozoa (D *d*). These spermatozoa have an ovo-conical head, with a caudal filament of extreme tenuity; the head is about $\frac{1}{3000}$th of an inch in its longer diameter, and about $\frac{1}{9000}$th in its shorter. The tail is attached to the wide end.

In attempting an interpretation of the above appearances, we must, I think, regard the nucleated cells which constitute the contents of the gonophore in the second of the stages just described as spermatic cells which in the next stage have set free their nuclei; these nuclei, after liberation from the cells, acquiring a more elongated form, developing a filament, and becoming converted into true spermatozoa.

Allusion has been just made to the peculiar striated appearance presented by the mature spermatic mass while yet contained within the gonophore. This appearance, which is very common in the mature male gonophores of the Hydroida, suggests to us the idea that the corpuscles composing the mass are confined in an exceedingly fine tubular tissue. I have, however, in vain sought for any indubitable evidence of tubes, and I believe that the appearance in question is the result of a mere arrangement of the corpuscles—a condition induced in the plastic mass by the pressure exerted on it by the resisting walls of the gonophore as the mass within increases in volume; for the component corpuscles have now become changed from the spherical form of the previous stage to a more oval form, and their axes are compelled by the surrounding pressure to take a definite direction. It is a phenomenon which in this view would be purely physical, and which we cannot avoid comparing to that of slaty cleavage, though occurring in an organized and living mass.

Origin of the Generative Elements.—Throughout the whole of the HYDROIDA the generative elements originate between the endoderm and ectoderm, and, with one exceptional condition to be presently described, are always formed in the walls of an organ strictly homologous with the manubrium of a gymnophthalmic medusa.

This organ forms the axile diverticulum in the young adelocodonic gonophore, and the manubrium of the sexual medusa while it is represented by the sexual zooid which buds from the radiating canals in the gonoblastocheme or non-sexual medusa.

It is not at first easy to say whether the generative elements have their proper origin in the ectoderm or endoderm of this body, as in most cases they can be merely seen filling the space between these two membranes, which become more and more separated from one another as the included mass of ova or spermatozoa increases in volume.

From some favourable observations, however, which I have succeeded in making on certain species of hydroids, I have convinced myself that the true origin of the ova and spermatozoa is to be found in the endoderm, while the ectoderm serves merely as a confining and protecting sac until such time as the generative elements acquire sufficient maturity to allow of their liberation, which always takes place by simple rupture or absorption of the ectodermal sac.

Thus in the gonophores of the male colonies of *Sertularia polyzonias* the spermatogenous tissue may be seen filling the entire space between the long cylindrical axile spadix and the surrounding walls of the gonophore. In most specimens it may be easily seen that the spermatogenous mass is far from being of uniform maturity throughout; for while towards the axis of the gonophore it is still very immature, the mother cells being here distinctly visible with the ultimate spermatic cells within them, we find that towards the periphery it consists of free active spermatozoa. The youngest portion of the mass is thus that which is still in contact with the spadix or endodermal portion of the gonophore, while the oldest portion is situated externally, being in contact with the confining ectoderm—a condition which would be scarcely possible if the ectoderm, rather than the endoderm, gave origin to the spermatic cells.

A state of things exactly parallel to this may be seen in the female gonophores of *Coryne pusilla*. At an early period in the development of these gonophores, the large thick spadix may be seen to be surrounded by a granular plasma, throughout which numerous minute nucleated cells are scattered. These cells I regard as the germinal vesicles and spots of the future ova, round which no distinctly differentiated vitellus can as yet be detected. In a more mature stage of the gonophore, while the same peculiar tissue continues to invest the spadix, the peripheral portion of this tissue may be seen to be thrown off in the form of undoubted ova, consisting each of a germinal vesicle and spot precisely similar to those observed in the more central portion of the mass, but now surrounded by a very definite vitellus. When the gonophore has attained complete maturity, the whole of the plasmatic mass has become metamorphosed into fully formed ova.

In *Coryne pusilla* and many other species, the ova, when escaping from the gonophore under the pressure of the compressorium, present a peculiar appearance. They are then seen to be each invested by a special membrane of great delicacy, which is continued backwards by a narrow neck-like prolongation; so that in this state the whole ovum presents a pyriform shape. This membrane is probably nothing more than the vitellary membrane of the ovum, which, from the mode in which the pressure is applied, assumes the form described.

I have spoken above of an exception to the all but universal fact that the generative elements originate between the ectoderm and endoderm of a body homologous with the manubrium of a naked-eyed medusa. The exception referred to consists in the origination of ova in the blastostyle, as may be seen in *Sertularia pumila* and one or two other species of *Sertularia*.

In *Sertularia pumila* a solitary gonophore of the ordinary form, and containing in the usual way ova or spermatozoa, originates, as in other cases, by

a bud from a blastostyle. In the female colonies, however, nucleated spherical bodies, in no way distinguishable from young ova, are found in the walls of the blastostyle itself, between whose ectoderm and endoderm they seem to lie (fig. 9 *k*). I have not succeeded in satisfactorily tracing the destination of these bodies; but I have reason to believe that the true gonophores bud forth from that part of the blastostyle in which the nucleated bodies occur, and that these, as young ova, pass from the blastostyle into the budding gonophore, where they would then naturally occupy their normal position between the endoderm and ectoderm of the manubrium, destined to undergo there a further development before being discharged into the acrocyst, which, as we have already seen, exists in this species. Each gonophore, after having performed its duty as a receptacle, in which certain intermediate stages of development take place, would seem to disappear, and be succeeded by another, which in a similar way receives its young ova from the blastostyle on which it buds *.

IV. Comparison of the Sexes in the Hydroida.

The existence of differentiated sex in the Hydroida was first announced by Ehrenberg †, who maintained that the so-called "egg-capsules" in *Coryne*, *Sertularia*, &c., had the significance of special fertile animals to which he gave the name of females, while he regarded the ordinary polypites as the sterile individuals of the colony.

With this announcement we may date a well-marked era in the history of progressive discovery among the Hydroida; for it is to the happy conception of Ehrenberg that we must refer the more philosophic views which within the last few years have so greatly advanced our knowledge of the structure, functions, and relations of these animals.

The celebrated German micrologist, however, did not grasp the full meaning of the facts of which he had thus so nearly given us the exact interpretation; for he regarded the central column (blastostyle) of the gonangium in *Sertularia* as the equivalent of the central diverticulum (spadix) in the gonophore of *Coryne*, while he viewed the gonophores borne on the sides of the blastostyle in *Sertularia* as merely eggs equivalent to the true eggs contained in the gonophore of *Coryne*.

The doctrine of the sexual differentiation of the Hydroida was confirmed by Lovén in a remarkable memoir originally published in the Transactions of the Royal Swedish Academy for 1835, and thence translated into Wiegmann's Archiv ‡. In this memoir Lovén gives an account of those singular extracapsular medusiform gonophores which are described above (p. 375) under the name of "meconidia;" he found them in a species of *Laomedea* (*L. Lovéni*, Allm.), and recognizes in them their true sexual function. He also describes the occurrence of medusiform gonophores in two species of *Coryne*; and having observed that in the gonophores of one of these species the cavity of the umbrella was filled with ova, he distinguishes them from

* Bodies undoubtedly of the same nature as those here described, but without any indication of a nucleus, are figured by Agassiz in an American species which he regards as identical with the *Sertularia pumila* of Europe. He, however, makes no allusion to them in the text of his work (*op. cit.* pl. 32. f. 9). They are described also by Lindström, *op. cit.*

† Corallenthiere, Abhandl. der Königl. Akad. der Wiss. zu Berlin, 1832. Erst Theil, S. 333.

‡ Beiträge zur Kenntniss der Gattungen *Campanularia* und *Syncoryne*, Wiegm. Arch. 1837. Erster Band, S. 239.

mere organs, and regards the gonophores in both instances as special female animals*.

Naturalists had now not only become familiar with the presence of true ova in the HYDROIDA, but they saw in the portions of the colony set aside for their production something more than mere organs. No one, however, had as yet discovered any trace of spermatozoa; Ehrenberg at this time makes no mention of a male element, while Lovén calls the nutritive polypites male, and in this view of their nature falls behind Ehrenberg, who more truly names them sterile or sexless individuals.

The doctrine of the sexuality of the HYDROIDA now waited only for the discovery of the male element in order to receive its complete development. This discovery was made by Ehrenberg, who, in 1838, pointed out the real nature of certain conical tubercles which at particular seasons are developed on the body of the freshwater hydra, and had been by previous observers regarded as a peculiar disease to which this animal was supposed to be subject, but which were now shown by Ehrenberg † to be true spermatophorous capsules, while a further and important step in this direction was made by Krohn, who a few years afterwards announced that he had, in the *Pennaria Cavolini*, Ehren., found certain receptacles similar in form to the ovigerous ones long ago described by Cavolini in the same remarkable hydroid, but containing spermatozoa instead of ova. Similar observations were made on *Tubularia indivisa* and on *Eudendrium racemosum*, as well as on *Aglaophenia pluma* (*Plumularia cristata*) and the *Sertularia misenensis* of Cavolini, in all of which Krohn succeeded in detecting spermatozoa ‡.

It is now certain that every species of hydroid gives origin to male and female zooids (or, in case of such medusæ as may be directly developed from the egg, to male and female sexually generated individuals), one destined for the production of ova, the other for that of spermatozoa. The separation of the sexes in distinct generative zooids, or in distinct individuals of a sexually generated offspring, is thus absolute and universal among the HYDROIDA. In by far the greater number of cases the separation is carried even further than this; for we scarcely ever meet with male and female gonophores in the same colony. As an almost universal rule, then, the HYDROIDA are diœcious; in other words, every colony is unisexual §.

Some few cases of a monœcious condition, however, occur. This has been noticed by many observers in the freshwater Hydræ ||, where indeed it is the most usual condition. I have found it also in *Plumularia pinnata*, which sometimes carries on the same stem both male and female gonophores. In *Dicoryne conferta* too there may generally be found, among the dense forest of stems with which the hydroid invests the surface of univalve shells, some stems carrying male and others female gonophores. Each stem, however, carries gonophores of one sex only, though it would seem that both male and

* It may here be noticed that Wagner had already (Isis, 1833, § 256, tab. xi.) found medusa-like gonophores, filled with ova, in a hydroid which he names *Coryne aculeata*; but, not being aware of the doctrine of Ehrenberg only just announced, the exact significance of these bodies escaped him.

† Mittheil. aus den Verhandl. der Gesellsch. naturf. Freunde in Berlin, 1838.

‡ Krohn, Einige Bemerkungen und Beobachtungen über die Geschlechtverhältnisse bei den Sertularinen, Müller's Archiv, Jahrg. 1843, S. 174.

§ Krohn had already noticed that, in all the species examined by him, the male and female gonophores were borne on separate colonies (*loc. cit.* p. 181).

|| See especially Prof. Allen Thomson "On the co-existence of ovigerous capsules and spermatozoa in the same individuals of *Hydra viridis*," in Proc. Roy. Soc. Edin., No. 30, 1845–47.

female stems are united by the creeping stolon into a common colony. In *Hydractinia*, on the other hand, whose habit is entirely similar to that of *Dicoryne*, we never meet with the two sexes in a common colony; perhaps even never investing the same shell.

As a general rule, there is no perceptible difference between the male and female colonies of the same species, either in the trophosome or the gonosome, beyond what is, of course, presented by the generative elements themselves. In some cases, however, the difference is sufficiently well marked. Thus in *Sertularia tamarisca* the male and female gonangia differ strikingly from one another; for the male gonangia are compressed, somewhat obcordate receptacles with a short terminal tubular aperture; while the female are oval for about the proximal half of their height, and then become trihedral with the sides diverging upwards, the whole being terminated by a three-sided pyramid whose edges are cut into two or three short teeth, and the basal angles prolonged into a short spine*.

So also in *Sertularia rosacea* a well-marked difference may be seen. The male gonangia are here of a conical form, curved near the apex, which is their point of attachment, and provided with six longitudinal ridges in the form of thin projecting lamellæ, each of which terminates at the distal extremity in a free pointed process which arches over the summit of the gonangium. In the female gonangium the longitudinal ridges are eight in number, while two opposite ones being greatly more developed than the others give to the gonangium the very elegant and striking form which caused Ellis to compare it to a "lily or pomegranate-flower just opening." The female gonangium of both *Sertularia rosacea* and *S. tamarisca* differs still further from the male by the remarkable marsupial chamber which I have already described as developed within it.

It will also be borne in mind that, in those species which develope an acrocyst on the summit of the gonangium, this body is formed only in the female; while it is on the female gonangium alone of *Halecium halecinum* that the little geminate polypite already described is produced; and to these cases we may also add the difference presented by the male and female meconidia in *Laomedea Lovéni*.

Among the gymnogonial Hydroida also, certain differences may be occasionally observed between the male and female. Thus in certain *Tubulariæ*, the tentaculoid tubercles which crown the gonophore are more fully developed in the female than in the male; but the most striking difference is found in the genus *Eudendrium*, whose male gonophores are situated in a verticil on the body of the polypite, and present the remarkable polythalamic condition already described, while the female gonophores originate irregularly for some distance backwards on the branch, and are always monothalamic. This difference between the male and female gonophores in *Eudendrium* struck Cavolini long before the presence of a male element in the HYDROIDA was suspected, and led him to suppose that *Eudendrium* reproduced itself by two different kinds of eggs. In accordance with this view, he called the female gonophores in his *Sertularia* (*Eudendrium*) *racemosa*, "uova a racemo," and the male gonophores "uova a corimbo"†.

The differences above described between the male and female are all confined to the gonosome; the trophosome, however, does not appear to be always exempt from a participation in sexual difference, for in *Hydractinia polyclina*,

* It is apparently the male gonangia which Ellis has figured in his description of this species.

† Cavolini, Mem. Polypi Marini, 1785.

Agass., the sterile polypites of the male colony are described as differing from those of the female colony by their more elongated proboscis*.

V. Development.

Reproduction in the Hydroida is sexual and non-sexual, the former taking place by means of ova and spermatozoa, the latter by buds and occasionally by spontaneous division.

A. *Non-sexual Reproduction.*

a. *Gemmation.*

Reproduction by gemmation is the phenomenon which, of all others, most vividly impresses us in our study of the Hydroida, and is that which confers upon this remarkable group of organisms their peculiar and characteristic physiognomy. It struck with all its force the earlier observers, and united with the flower-like form of the polypite in suggesting the term "zoophyte" by which the wonderful budding and blossoming plant-like animals which adorn our rocks at low water, and are dredged up at various depths from the bottom of the sea, have long been known to the naturalist.

Gemmation in the Hydroida has for its object, 1, the extension of the trophosome; 2, the formation and extension of the gonosome.

The primordial trophosome is quite simple; but it soon begins to complicate itself by budding, and this complication is frequently carried to a great extent, the primary buds giving rise to secondary buds, and these again to tertiary, while buds of a fourth, fifth, or even higher order may continue to be produced in succession; and as every bud may develope itself into a branch, the result will be the production of those complicated dendritic groups which attain to such perfection in numerous species among the *Tubularian, Campanularian,* and *Sertularian* hydroids.

The complex trophosome which thus results from successive buddings may present symmetrical or asymmetrical forms. Symmetrical forms are, as a general rule, presented throughout the *Sertularians*; the polypites, with their hydrothecæ, being in these hydroids developed upon points which are symmetrically disposed in relation to a common axis or a common plane; while the ramification of the trophosome is here also usually symmetrical—distichous in most species, verticillate in others. The *Campanularians,* on the other hand, and especially the *Tubularians,* present in most cases an asymmetrical disposition of their polypites, and, as a necessary consequence, an asymmetrical ramification. The genus *Pennaria* among the *Tubularida* affords a remarkable exception in this respect, its gemmation being so singularly symmetrical as to give to the entire trophosome a close resemblance to that of a *Plumularia*—so close, indeed, as to have led the earlier systematists to place it in this genus.

Under the general head of Gemmation, we may here consider the development of the polypite, the development of the gonoblastidium, and the development of the gonophore.

1. *Development of the Polypite.*

It is exceedingly rare to find the trophosome retaining through life the simple condition which it presents during its primordial state. Cases, however, of permanently simple trophosomes occur. We meet with them,

* Agassiz, Nat. Hist. United States, vol. iv. p. 228.

for example, in *Corymorpha* and certain allied forms, and apparently also in the curious free trophosome of *Nemopsis*, as described by M^cCrady, and of *Acaulis*, as described by Stimpson*.

Polypite-bud in the Tubularida.—When a polypite-bud is about to become developed from any part of the cœnosarc in the *Tubularida*, the two layers of the cœnosarc are seen at this spot to be pushed outwards as if by an incipient hernia, and the little hollow tubercle thus produced forces before it the investing periderm, which is first extended over the advancing bud, and is at last absorbed or ruptured.

The little bud, however, has been in the mean time clothing itself with a new periderm, which, now that it has escaped from the confinement of the old one, is seen to cover it with a very delicate, transparent, structureless pellicle. The bud continues to increase in size, becoming longer and thicker, with its endoderm and ectoderm very distinct, and with its cavity opening freely into that of the branch from which it springs, and admitting into its interior the fluid with the floating granules, which fill the general cavity of the cœnosarc, and which are kept in a state of active rotation within the bud. It continues to enlarge, but has its distal extremity still closed, while the entire bud is still invested by its delicate periderm.

We next find that the little bud has acquired a somewhat clavate form by the enlargement of its distal extremity. While the periderm which clothes the growing bud continues, by means of new layers deposited upon its inner surface, to increase in thickness over the whole bud, except at its extremity, these new layers cease, in almost every case, at a very early period to be excreted from the free extremity of the bud, and the periderm here accordingly remains in the condition of a transparent structureless pellicle, of extreme tenuity, in which state it may often be found in the fully developed polypite, though it is also frequently impossible to demonstrate its presence after the polypite has attained its complete form.

Whether this delicate continuation of the periderm remains through the life of the polypite or entirely disappears at an early period, we now find tentacles begin to grow out from the enlarged extremity of the bud, and a terminal mouth to become developed; the form is thus gradually assumed which is to characterize the adult polypite.

In some cases, however (*Coryne vaginata*, Hincks, and *Eudendrium vaginatum*, Allm.), the periderm which clothes the free extremity of the growing branch attains considerable thickness, and does not disappear until a later period; but it ceases in such cases to be in close contact with the ectoderm, and the polypite continues to become developed within an outer chitinous capsule; and this development proceeds to the formation of tentacles and the assumption, more or less, of the adult form by the polypite-bud, before the rupture of the enclosing capsule places the young polypite in direct relation with the surrounding water†.

The development of the polypite-bud in *Hydra* seems to be, in all essential points, the same as in the *Tubularida*, the most important differences being those which depend on the absence of a periderm in *Hydra*. The ultimate destination of the bud, however, is very different in the two cases; for while

* It seems to me, however, still a question whether the free hydroids described by the American observers as *Nemopsis* and *Acaulis* be not the detached polypites of a fixed Tubularidan which may possess the habit of throwing off its polypite-heads, as we know to be the case in certain European species of *Tubularia*. (See below, p. 391.)

† A very unusual condition is presented by *Bimeria nutans*, Wright, in which the periderm is continued as a thick closely investing tunic over the whole of the polypite, except the tips of the tentacles and a small space just behind the mouth.

it remains fixed as a permanent part of the hydrosoma in the *Tubularida*, it is in *Hydra* destined to become detached and enjoy henceforth an independent existence.

Decapitation and Re-formation of successive Polypite-heads. Polarity of the Hydroid.—Our account of the development of the polypite-bud in the *Tubularida* would be incomplete without some reference to a very remarkable phenomenon presented by certain species of *Tubularia*, namely, the periodical shedding and renewal of the polypite-heads. This phenomenon was several years ago observed by Dalyell*, and described with all his usual accuracy by this excellent observer. I cannot find, however, that any author has followed the process with that exactness which is necessary to enable us to form a correct idea of its nature. My own observations have been principally made on *Tubularia indivisa*, where I have bestowed upon the process in question a very careful examination.

When the polypite of this species, with its clusters of gonophores, has acquired full maturity, the time is come when it is to be cast off and its place taken by a successor. A breach of continuity now occurs in the endoderm of the stem at a short distance behind the polypite; while the ectoderm having already become detached from the endoderm in the space between this breach and the base of the polypite, the endoderm of the upper end of the stem slips out of the ectoderm, carrying the polypite with it, and leaving behind it the empty ectoderm as a thin, collapsed, membranous sheath, surrounded by the periderm, which here exists as a very delicate loose pellicle.

The polypite thus detached falls to the ground, where it retains for some time its vitality, the gonophores which still hang from it discharging such of their contents as had not escaped before the decapitation.

In the mean time the wound which had been formed in the cœnosarc by the detachment of the polypite heals over, and the truncated end of the cœnosarc becomes closed.

Two slight constrictions, one a little behind the other, are next seen to take place in the cœnosarc at a short distance from the decapitated extremity, while the peculiar tubular lacunæ which exist in the cœnosarc of *Tubularia*, and which had hitherto extended as separate canals through the whole cœnosarc of the stem, now coalesce in front of the anterior constriction, where they form a single cavity by the breaking down of the partitions of endoderm which had up to this time separated them from one another.

A girdle of minute tubercles may next be seen budding forth from the cœnosarc, at the site of the posterior constriction. These soon become extended into tentacles, which embrace the anterior part of the cœnosarc, round which they appear twisted in a very elongated spiral.

In the next stage a similar zone of tubercles, becoming, like the others, elongated into tentacles, shows itself close behind the anterior constriction; and there are thus established the two sets of tentacles, the posterior and anterior ones of the new polypite.

By the elongation of the cœnosarc from behind, the new polypite is gradually lifted up out of the tube of the periderm, when the tentacles, having room to expand, immediately fall into their normal position, while the rudimental clusters of gonophores may be seen as minute lobulated elevations between the anterior and posterior series of tentacles, and the free extremity of the polypite has by this time become perforated by a mouth.

The polypite now increases in size, raised higher and higher on the elongating cœnosarc, which clothes itself with a periderm as it lengthens, and the

* Rare and Remarkable Animals, 1847, vol. i. p. 4.

polypite with its clusters of gonophores, having finally attained complete maturity, is then in its turn cast off, to be succeeded in an entirely similar way by a new one.

The formation of successive polypites is always accompanied by a periodical elongation of the stem, and this is indicated by annular markings of the periderm separated by rather wide intervals, each interval corresponding to a single decapitation and renewal.

From the above description it will be seen that the formation of successive polypites is not so much a process of ordinary budding, as a true metamorphosis of the decapitated extremity of the cœnosarc.

In connexion with the phenomena now described, those which accompany the artificial section of the stem may here be mentioned. When the stem is cut across, the cœnosarc of the upper segment soon heals over at the place of section, the tubular lacunæ become again closed, and the cœnosarc now begins to grow downwards through the cut extremity of the periderm, presenting the same lacunar structure as in the older portions, and excreting upon its surface a very delicate periderm. The well-known cyclotic currents may generally be seen with great distinctness in the fluid which fills the tubular lacunæ of the young elongated cœnosarc.

The lower segment, on the other hand, instead of pushing forth from the cut extremity a simple continuation of the cœnosarc, developes from this extremity a polypite*. There is thus *manifested in the formative force of the Tubularia-stem a well-marked polarity*, which is rendered very apparent if a segment be cut out from the centre of the stem. In this case, no matter in what position the segment may lie, that end of it which was directed downwards or proximally while it formed a part of the unmutilated hydroid will never develope a polypite, but will extend itself as a simple cylindrical prolongation of the cœnosarc; while the upper or distal end, instead of becoming simply elongated, will shape itself into a true polypite; and all this though of course not the least difference in structure or form can be detected between the two extremities at the time of section.

It is further manifest from these facts that when the hydroid is placed under conditions which allow of perfect freedom of growth, there is no such thing as a stationary extremity, both ends being really growing ends, while there exists in every segment a neutral plane midway between the two ends.

Polypite-bud in the Campanularida and Sertularida.—In the development of the bud, the Campanularian and Sertularian hydroids differ in some important features from those which characterize the process just described. It may be easily watched in many species, as, for example, in *Laomedea flexuosa*. We may here see it proceed, in the first place, to the formation of a hollow cylindrical branch, whose cavity is in free communication with that of the cœnosarc, and whose distal extremity ends in a cul-de-sac invested, like the rest of the young branch, by the chitinous periderm. Up to this point the phenomena are precisely similar to what we have just seen in the *Tubularida*; but now the distal extremity of the branch begins to enlarge, and at the same time continues to coat itself with a chitinous periderm in the form of a capsule, which acquires increased thickness by successive deposits of new matter to its inner surface, thus contrasting with the thin pellicle which forms the temporary capsule in certain *Tubularida*.

The extremity of the branch now presents the shape of an inverted cone,

* The observations of Dalyell, who has made numerous experiments on the section of the stem in *Tubularia indivisa*, are here quite in accordance with my own. (See Dalyell, 'Rare and Remarkable Animals,' vol. i. p. 23.)

plainly recognizable as the body of the budding polypite, invested with a strong chitinous covering, which is closely applied over its whole surface, and is continuous below with the periderm covering the rest of the branch. The interior of the young polypite is hollowed out into a wide cavity lined by a layer of loose cells—the most internal cells of the endoderm—which are filled with a granular pigment.

The conical enlargement at the extremity of the branch continues to increase in size, and we soon see the soft parts within become contracted towards the proximal end of the cone, where they withdraw themselves from contact with the walls of the chitinous capsule, which had up to this time closely embraced them. At the wide or distal end of the cone they still remain adherent to the capsule for some distance downwards, while at the proximal end itself there is also a distinct but narrow zone of contact and adhesion maintained between the internal soft parts and the external chitinous capsule. In the cavity which occupies the interior of the soft contents of the capsule very distinct rotating currents may be now seen, excited doubtless by the action of vibratile cilia, though a direct view of these cilia cannot be obtained through the thickness of the walls.

Between the proximal and distal zones of contact, the internal structures become more and more withdrawn from the walls of the capsule, while the whole body continues to elongate; and this may now be seen in the form of a cylindrical column occupying the axis of a conical cup of chitine, and expanded below into a narrow ring, which at this point connects it with the walls of the cup, while, above, it expands into a broad disc which fills up the distal extremity of the cup, like a lid or plug. The axis of the column is permeated by a tubular cavity in continuation below with the cavity of the branch, and expanding above into a wide chamber which occupies the interior of the plug-like enlargement of its distal end. It is now plain that, while the soft contents of the cup are the developing polypite, the cup itself is to become the hydrotheca.

The excreting of the chitine and the shaping of the hydrotheca would seem to devolve on the terminal plug-like disc alone, from the time that the lower parts of the nascent polypite had withdrawn themselves from contact with the walls of the external capsule; and as the polypite continues to elongate itself, the surrounding cup is extended at the same rate, by addition to its wider end from the sides of the disc, while the lower parts of the cup undergo little or no change.

The upper surface of the disc has been all along covered with a thin layer of chitine, whose periphery is continuous with the chitinous walls of the cup, but which does not interfere with the growth of the young polypite; for as the latter continues to extend itself, the layer of chitine on the upper surface of the disc is carried onwards before it, without becoming thereby detached from the side of the cup—a fact which we can scarcely explain otherwise than by supposing considerable extensibility in the recently deposited chitine of the cup. At last the hydrotheca has attained its complete size and shape, and now the young polypite becomes more or less retracted within it, the terminal plug-like disc withdrawing itself from the layer of chitine which it had excreted on its upper surface, and which is now left behind as a roof closing over the mouth of the cup.

The whole circumference of the retracted disc now begins to develope a circle of minute tubercles, which gradually elongate themselves into short thick tentacles, while the central part becomes elevated into a blunt conical proboscis (metastome), and the cylindrical tubular column which occupies the

axis of the hydrotheca has become dilated into a more oval-shaped body, with a wide internal cavity—the stomach of the developing polypite.

The young polypite, still included within a completely closed cup, presents greater and greater contractility, now withdrawing itself towards the bottom, and now extending itself through the entire height of the surrounding cup. The tentacles in the mean time have become longer, the extremity of the terminal cone has become perforated by a mouth, and at last the polypite pushes off the chitinous roof of its hydrotheca and emerges into free contact with the surrounding water.

2. *Development of the Gonoblastidium in the angiogonial Hydroida.*

Laomedea flexuosa will afford here too a very convenient subject for tracing the process of development. The gonoblastidia of this hydroid arise close to the axillæ of the branches, and present the form of a long cylindrical column (blastostyle), expanded at its summit into a disc, occupying the axis of an urn-shaped gonangium, and carrying along its whole length adelocodonic gonophores, which increase in maturity as they approach the summit of the column. The whole is elevated on a short annulated peduncle.

The gonoblastidium here originates in a bud precisely in the same way as a polypite; and up to the stage to which we have already followed the development of the polypite and hydrotheca, when these parts present the condition of a conical enlargement of the extremity of the branch, there cannot be found any difference between the polypite-bud and the gonoblastidium-bud. It would seem, however, that at this stage the soft parts, instead of absolutely withdrawing themselves from contact with the external chitinous capsule, present in their ectodermal layer a number of lacunæ, which, increasing in size, become confluent with each other, and the ectoderm thus becomes split into two layers by a true *chorization*; the external layer remains in contact with the chitinous capsule, while the internal layer, remaining adherent to the endoderm, becomes more and more withdrawn towards the axis of the bud, where it now constitutes the external or ectodermal layer of an axile column or blastostyle. The capsule thus becomes lined with a thin layer of ectoderm, which is continuous with the ectoderm of the blastostyle only at its distal and proximal extremities, these two membranes being in the whole of the intermediate region separated from one another by a wide interval. This interval, which constitutes the cavity of the developing gonangium, is thus nothing more than a large lacuna; and it is into this lacuna that the gonophores now begin to bud forth from the axile column. The excreting and modelling of the chitinous gonangium would seem to devolve for some time still on the ectodermal lining, instead of being, as in the polypite-bud, transferred at a very early period exclusively to the disc-like summit of the axis. After a time, however, the lining membrane entirely disappears, and henceforth the excreting and modelling of the gonangium seems to devolve on the terminal disc of the blastostyle. While the gonangium is yet young, numerous irregular fleshy bands may be seen stretching across the cavity from the blastostyle to the external wall. These bands are the remains of the original union between the two layers into which the ectoderm has split. They are generally torn, and disappear as the gonangium, increasing in size, has its walls more and more widely separated from the blastostyle; but they are also occasionally more or less visible in the full-grown gonangium.

A comparison between the developing polypite and its hydrotheca, on the one hand, and the developing blastostyle and its gonangium, on the other,

affords a most instructive parallelism, showing the close connexion between the polypite and the blastostyle. If in the polypite-bud the development were arrested at the point to which it arrives just before the terminal disc has withdrawn itself from the roof of the young hydrotheca, in order to develope its tentacles, we should have in almost every particular a gonangium with its blastostyle. The development of a mouth and tentacles, however, points towards a different destination; and now, instead of producing sexual zooids, it applies itself solely to the nutrition of the colony.

The gonangium does not always present the simple form which we find in *Laomedea flexuosa*, and we have already seen the remarkable modification which it undergoes in the female colonies of *Sertularia rosacea* and *S. tamarisca*, by the formation of a marsupial chamber for the protection of an extracapsular sac, in which the ova are retained during the earlier periods of their development.

3. *Development of the Gonophore.*

The Adelocodonic Gonophore.—The development of the adelocodonic gonophore, in its simplest form, may be easily studied in *Hydractinia echinata*. In this hydroid the gonophores are borne on a gonoblastidium (fig. 2 *bb*, *c*), which here, just as in the blastostyle of the *Sertularida* and *Campanularida*, is morphologically nothing more nor less than an arrested nutritive polypite, but in *Hydractinia* never developing a gonangium.

In their earlier stages the gonophores may be seen as minute hollow tubercles, projecting from the sides of the gonoblastidium. They are composed of two layers, endoderm and ectoderm, directly continuous with the corresponding layers of the gonoblastidium, with whose cavity that of the young bud is in free communication. At first we can detect no change beyond a simple increase in size; but we soon find the ectoderm separated from the endoderm by the interposition of a minutely granular mass between them. This mass constitutes the basis of the generative elements, and is afterwards to become ova or spermatozoa. In the mean time the ectoderm has itself become differentiated into two layers; and we have thus laid down the foundation of all the parts which we meet with in the full-grown gonophore. The wall of endoderm which surrounds the central cavity of the developing gonophore, and is itself immediately surrounded by the generative elements, is the spadix; the more internal of the two layers into which the ectoderm has divided is the endotheca, the more external the ectotheca.

The gonophore now becomes more and more distended by the increasing volume of the generative mass, while the spadix at the same time continues to grow, and now constitutes a club-shaped hollow organ extending through the axis of the mass, while floating particles from the cavity of the gonoblastidium are freely admitted into its interior, where they may be seen performing active rotatory movements.

The sex of the gonophore becomes evident at an early period, by the appearance of ova with their germinative vesicle and spot in the generative plasma of the female, while in the male the interval between spadix and endotheca continues still to be occupied by a uniform grumous plasma, in which, at a somewhat later period, spherical cells and ultimately free-moving spermatozoa may be detected.

The gonophore of *Hydractinia echinata* does not pass to any higher grade of development than that here described; but in some other forms of adelocodonic gonophore a further differentiation takes place by the development of

an additional membranous sac or mesotheca, with gastrovascular canals, between the endotheca and ectotheca (*Tubularia indivisa*) (fig. 6 C). I have never succeeded in following the development of the mesotheca, and cannot say under what condition it begins, or how it proceeds, the membrane appearing always fully formed from the moment it is recognizable. It is, however, by no means improbable that it grows up as a cup from below, beginning along the line where the endotheca and ectotheca are continuous with one another.

It will be seen that in the above account I differ in some important points from the interpretation given by Agassiz to the appearances which present themselves in the development of the adelocodonic gonophore. In his account of this process in *Clava leptostyla*, Agass., Agassiz* regards the walls of the gonophore as simple, and as homologous with the umbrella of a medusa. In *Clava multicornis*, however, the existence of two membranes may with care be demonstrated in these walls, though I admit that I have frequently failed in detecting more than a single one. In no case, however, can the walls of the gonophore in *Clava* be regarded as the homologue of an umbrella. When two membranes can be demonstrated in them, these will be an endotheca and ectotheca; if only a single membrane be present, as Agassiz believes to be the case in his *Clava leptostyla*, this will be an endotheca, while the part which would really represent an umbrella, namely a mesotheca, is not developed†.

Again, in the gonophores of *Hydractinia polyclina*, Agass., *Parypha crocea*, Agass., and *Thamnocnidia spectabilis*, Agass., Agassiz correctly figures the two membranes which enter into their walls; but he assuredly assigns an incorrect origin to the more internal of these membranes when he describes it as rising, subsequently to the formation of the generative mass, from the proximal end of the gonophore in the manner of a cup closely pressed against the outer wall, and, at least in *Hydractinia* and *Thamnocnidia*, ultimately closing over the contained structures so as to form a continuous internal wall.

Now the internal wall in the gonophore of *Hydractinia* is undoubtedly formed, not *after*, but simultaneously with the appearance of the generative mass, and is nothing more than the internal of the two layers into which the ectoderm of the primary bud has become divided simultaneously with its separation from the endoderm by the interposition of the generative elements; it is thus the endotheca of the sporosac, while the more external layer is the ectotheca.

Having had no opportunity of examining the development of the gonophore in *Parypha* or *Thamnocnidia*, I am unable to bring any direct observations into opposition with the views of Agassiz as to the gonophores of these genera; but the analogy of *Hydractinia* and of other hydroids, whose adult gonophores correspond in all essential points with those of the American forms, leads me to believe that the process is in all the same as in *Hydractinia*.

It is only in those cases where a mesotheca becomes developed, as in *Tubularia indivisa*, that the adelocodonic gonophore presents any true representative of the umbrella of a medusa, the mesotheca being properly the homo-

* *Op. cit.* vol. iv. p. 221.

† In my earlier researches into the anatomy of the reproductive system in the *Hydroida* ("On the Anatomy and Physiology of *Cordylophora*," Phil. Trans. 1853), I entertained the view here maintained by Agassiz, as to the homology of the parts in question. Subsequent more extended observations, however, have induced me to modify in some respects the views then expressed, and to adopt those which are advocated in the present Report. (See my paper "On the Reproductive Organs of *Sertularia tamarisca*," in the Report of the British Association for the Advancement of Science, 1858.)

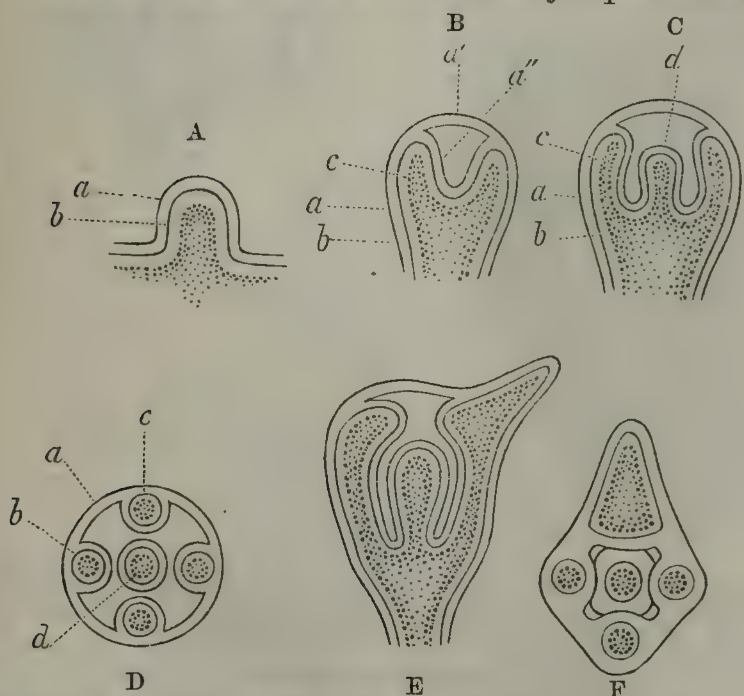
logue of this part. Agassiz, in his account of *Tubularia Couthouyi*, Agass., ignores the existence of any membrane between the well-developed mesotheca of this species and the generative mass which surrounds the spadix. In *Tubularia indivisa*, however, this membrane cannot be overlooked, especially in the male, though in the female it would seem to disappear at an early period, and may thus escape detection.

The Phanerocodonic Gonophore.—The phanerocodonic gonophore shows itself, at first, in every case as a minute hernia (fig. 15 A), consisting of endoderm and ectoderm, and having its cavity in free communication with that of the gonoblastidium or of the trophosome from which it springs, thus in no respect differing at this period from the corresponding stage in the development of the adelocodonic gonophore, or indeed in that of a polypite branch.

It is very difficult to follow satisfactorily the several steps by which this primordial tubercle becomes ultimately converted into a medusa. I have bestowed great attention on it in different species of HYDROIDA, and have more recently subjected the development of the medusa-bud in *Corymorpha nutans* to a very laborious examination, which has led me to adopt the process now about to be described, as the true interpretation of the phenomena presented in this hydroid.

We first find that four equidistant processes (fig. 15 B *c*), consisting of endoderm and ectoderm, with an included cavity, which is a continuation of that of the hernia-like tubercle just mentioned, have begun to grow upwards from a

Fig. 15.—Development of medusa in *Corymorpha nutans.*



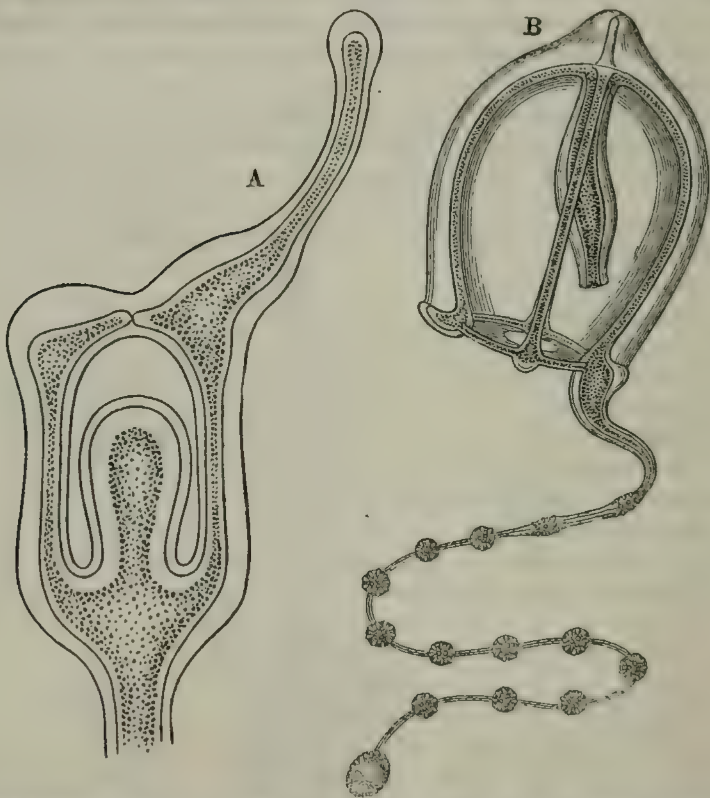
A, very early stage of medusa-bud when it presents the form of a simple hernia-like tubercle whose cavity is in communication with the somatic cavity of the hydroid; B, more advanced stage; C, stage still further advanced; D, transverse section of C; E, a stage still more advanced than C; F, transverse section of E.

a, ectoderm; *b*, endoderm; *a'*, more external of the two layers into which the ectoderm of the bud has split; *a''*, the more internal of these two layers; *c*, radiating gastrovascular canals; *d*, manubrium.

circle round the summit of this primordial bud. These, however, do not show themselves as free processes; for, simultaneously with their appearance, the ectoderm of the summit of the bud becomes split into two layers (a', a''), which become more and more widely separated from one another as the processes continue to elongate, the outer layer arching over the space which is surrounded by the four processes. During this elongation, the ectoderm which occupies the four intervals between the roots of the processes is carried upwards as a continuous membrane, stretching across from one process to another in the manner of a web.

The result of this is, that we have now the distal portion of the bud in the form of a deep cup formed of ectoderm, closed over by a layer also consisting of ectoderm, and having its walls traversed by four equidistant cæcal tubes, whose cavity is continuous with the original cavity of the bud, and which are lined by a continuation of the endoderm of the bud. There is no

Fig. 16.—Development of medusa in *Corymorpha nutans.*



A, medusa somewhat more advanced than E in fig. 15; the bulbous terminations of the gastrovascular canals have coalesced, and one of them has become projected into a long thick tentacle. B, medusa just after liberation from the trophosome.

difficulty in recognizing in these tubes the radiating canals of the future medusa, and in the web of ectoderm which unites them the umbrella.

From the central point of the area included between the bases of the four canals another hernial process (fig. 15 C *d* and D *d*) has already begun to make its appearance, composed of ectoderm and endoderm, and containing a prolongation of the original bud-cavity. It advances as a thick process in the axis of the cup, and is at once recognizable as the future manubrium.

The four peripheral processes continue to elongate, and are soon seen to be dilated into bulb-like expansions at their extremities (fig. 15 E, F). The bulbs increase in size, and come in contact by their sides; while one of them, enlarging much more rapidly than the three others, gives a marked preponderance to its side of the bud, and makes the distal end of the bud appear as if obliquely truncated. It then begins to extend itself beyond this distal end into a thick hollow tentacle.

In the mean time the four bulbs which had come in contact have coalesced, and their cavities now communicate with one another (fig. 16 A); but, by the gradual enlargement of the distal end of the bud, the bulbous ends of the radiating canals are again drawn away from one another: the communication, however, between their cavities is not thereby interrupted, but continues to be maintained by a tubular elongation of their original points of union; and in this tube we now recognize the circular canal of the medusa.

The cavity of the umbrella is still closed by the more external of the two laminæ into which the ectoderm had originally split at the distal end of the bud. In the final stage, this lamina is either perforated in the centre in order to form the velum, or, what I now believe to be more probable, it entirely disappears, and the velum is formed by a centripetal extension of the ectoderm on a plane with the bulbous extremities of the radiating canals, at the time when these bulbs are withdrawn from contact with one another in order to form the circular canal.

The manubrium, previously imperforate, has now acquired a mouth at its extremity. The solitary tentacle, too, has now become elongated, and presents its characteristic moniliform structure; the umbrella rapidly contracts and expands with vigorous systole and diastole; and the medusa at last hangs on its stalk, a true *Steenstrupia*, ready to break away from the restraint of its fostering polypite and enter upon an independent existence (fig. 16 B).

From the above account of the development of the medusa-bud, it will be seen that here also I am not entirely in accordance with the views expressed by Agassiz on this subject. The distinguished American naturalist gives a very detailed account of the process as he has interpreted it in the development of the medusa-bud springing from his *Coryne mirabilis*, and in which he describes this development as starting with the separation of the endoderm from the ectoderm in the primordial tubercle, and the inversion of the endoderm into itself, so as to form the cup of the future umbrella. "In doubling on itself, the retreating fold does not press closely on all points upon the stationary one, but leaves four equidistant spaces into which the chymiferous fluid penetrates." This mode of formation of the cup and radiating canals being admitted, the subsequent steps must proceed in a different way from that which I have described in *Corymorpha*; but as his account of it will scarcely admit of abridgment, I must refer to Agassiz's great work itself for the very complicated details of this process*.

McCrady† believes that those medusæ which occur among the *Tubularida* are developed in a different way from those which we find among the *Campanularida*. He describes the umbrella in the former as produced by an excavation of the substance of the young bud, forming thus a completely closed cavity in which the manubrium is included, and which only at a subsequent period becomes perforated at its summit to form the orifice of the umbrella. In the *Campanularida*, on the other hand, he believes that the umbrella grows up from below as a ring round the manubrium, which is thus

* Natural History of the United States, vol. iv. p. 192, &c.

† *Op. cit.* p. 110.

never included in a closed cavity, but is from the first directly exposed to the surrounding medium. In accordance with these views, M^cCrady divides the gymnophthalmatous medusæ into the "endostomata" and the "exostomata."

While I think it highly probable that differences will be found in the details of the development of the medusa-buds belonging to different species of the HYDROIDA, my own observations have not yet led me to adopt the above generalization of McCrady.

Formation of Buds by the Phanerocodonic Gonophore.—The phenomenon of budding does not necessarily find its extreme term in the formation of the gonophore. Many free-swimming medusæ, some of which are known to have originated in hydroid trophosomes, complicate themselves by gemmation, which manifests itself in the production of other medusa-buds upon various parts of their bodies. Among the examples of this phenomenon we may cite those which are seen in certain medusæ of the type described by authors under the name of *Sarsia*, all of which probably originate in *Coryne*-like trophosomes. In these medusæ, buds, which develope themselves into forms resembling that of the medusa which gives rise to them, spring from the manubrium or from the bulbous base of the tentacles. A fine example of the same phenomenon is afforded by the medusa of the tubularian hydroid, *Hybocodon prolifer*, Agass. In this beautiful animal, Agassiz* describes the base of the solitary tentacle which is continued from the distal extremity of one of the radiating canals of the medusa as itself producing a cluster of medusa-buds, which in time assume the form of the primary medusa, and may themselves repeat the same process, through the production of successive broods of similar buds, before they become detached as free natatory medusæ. Steenstrup has observed buds which he regarded as sexually developed from the base of the tentacles in a medusa which he refers to his *Coryne fritillaria*, while Greene has described the production of buds, not only from the bulbous base of the tentacles, but along the course of the tentacles themselves, in his genus *Diplonema*.

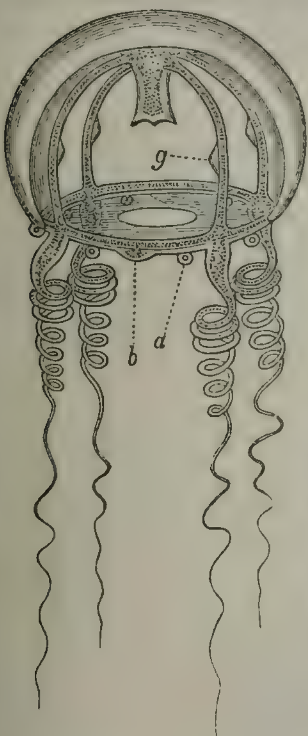
In the medusæ belonging to the family of the *Æginidæ*—a group, however, of which we have as yet no positive proof of any of its members being derived from a polypoid trophosome, though neither is there any proof of the contrary —it is probable that multiplication by buds formed upon the inner surface of the stomach is a constant and normal phenomenon. It would further appear that these buds detach themselves while still in a very immature state, and that, after becoming free, they undergo a metamorphosis before arriving at their adult form. From the remarkable observations of Kölliker and of Fritz Müller, referred to below (pp. 419, 420), it would seem indeed that there is here in some cases a heteromorphism, a difference of form being observed among successive broods of buds; but observations are still needed before we can arrive at any conclusion as to the ultimate destiny of these buds.

Among the successive broods of medusæ thus produced, whether by primary budding from the trophosome, or gonoblastidium, or by secondary budding from the primary one, there is, if we except certain instances just referred to among the *Æginidæ*, no heteromorphism; and every medusa in the series is not only similar to every other, but is probably capable of direct sexual maturity. In certain other cases, however, it is different. This we have already seen in the medusiform zooids, to which we have above given the name of "gonoblastocheme." In the medusa, for example, of *Campanularia Johnstoni* (fig. 17)—a medusa referable to the deep-belled section of the forms grouped together by Gegenbaur under the name of *Eucope*,—and in those of *Laomedea*

* *Op. cit.* vol. iv. p. 245. pl. 24.

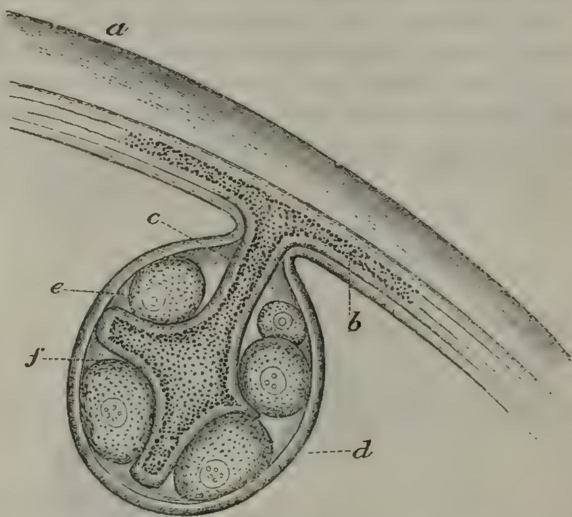
dichotoma and *L. geniculata*—medusæ referable to the type of *Obelia*, Pér.—sexual elements are never directly developed. For this purpose there is needed a new zooid (fig. 17 *g* and fig. 18) which no longer presents the developed me-

Fig. 17.—Medusa of *Campanularia Johnstoni* shortly after liberation from the gonangium, illustrating the peculiarities of the gonoblastocheme.



a, lithocyst; *b*, incipient tentacle; *g*, incipient sporosac, formed as a bud upon the radiating canal.

Fig. 18.—Reproductive sac (sporosac) budding from the radiating canals of the gonoblastocheme of *Obelia* (*Laomedea*) *geniculata*.



a, portion of umbrella and, *b*, radiating canal of the medusa; *c*, spadix of sporosac; *d*, wall of sporosac, consisting of endotheca alone; *e*, ovum, with germinal vesicle and germinal spot; *f*, ovum, with numerous germinal spots in the germinal vesicle.

dusal type, but, instead of it, the type of the adelocodonic gonophore. This zooid springs as a bud from the radiating canals of the medusa, and is constructed upon precisely the same plan as that which we meet with in the gonophore of *Clava* or *Hydractinia*, except that the ectotheca would seem to be absent. It has an axile spadix (fig. 18 *c*), whose cavity is in direct communication with that of the radiating canal from which it springs. Immediately investing the spadix are the generative elements, ova or spermatozoa; while these are themselves surrounded and confined by a true endotheca (*d*), which becomes at last ruptured for the liberation of its contents.

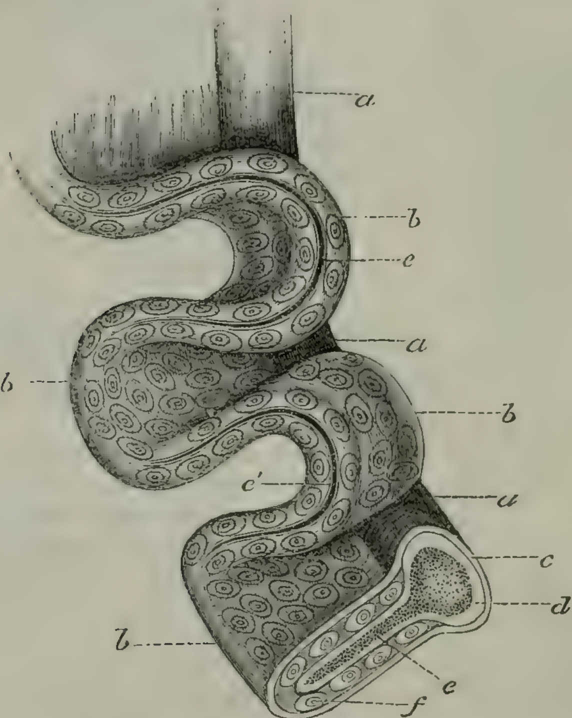
The zooidal nature of these buds is nowhere more distinct than in the genus *Aglaura*, Pér., a form not yet traced to a polypoid trophosome. Here the generative elements are produced in eight sac-like processes which surround the base of the manubrium, which is itself borne on the extremity of a stalk dependent from the summit of the umbrella. These sacs are undoubtedly true buds, and are entirely homologous with the gonophores of *Clava*; and it is plain that they are developed from the proximal extremities of the radiating canals, just where these canals pass off from the manubrium in order to run along the sides of the stalk before reaching the umbrella.*

* See Leuckart's description of *Aglaura Péronii* (Wiegmann's Archiv, 1856, Erster

In certain other naked-eyed medusæ, such as those belonging to the genus *Thaumantias*, Esch., the trophosome of which has been in one species detected by Wright, and the genera *Tiaropsis*, Agass., and *Tima*, Esch., which, like *Aglaura*, have not yet been traced to a hydroid trophosome, the reproductive buds are situated, as in *Obelia*, upon the radiating canals; but they occupy with their extended base a much greater length of these canals than the corresponding buds in *Obelia*, *Campanularia*, or *Aglaura* do. They possess thus a less defined and individualized appearance than in the last-named medusæ; but, notwithstanding this, they are constructed upon essentially the same plan, and afford no exception to the view here taken.

In *Tima*, indeed, we have an extreme case of this extension of the base of the generative buds, which here present themselves in the form of four long,

Fig. 19.—Portion of the reproductive band in a female medusa of *Tima Bairdii*.



a a a, radiating canal; *b b b*, reproductive band; *c*, ectoderm; *d*, endoderm; *e*, cavity of the spadix; *e' e'*, distal edge of the flattened spadix seen through the ectodermal layer; *f*, ova.

flattened, sinuous frill-like bands, each attached by one edge along the whole length of a radiating canal (fig. 19). When a section is made from the free to the attached edge of this band, the generative elements are seen to be disposed upon each side of a hollow longitudinal septum (*e*, *e'*). This septum consists of a diverticulum of the endoderm of the radiating canal; it admits into its interior the fluid which circulates in the radiating canal, and is plainly homologous with a laterally extended and flattened spadix; while the

Band, S. 10). Leuckart recognizes in the generative sacs of *Aglaura* the significance of true zooids, though he refrains from extending this view to the generative sacs of other medusæ.

generative elements are externally confined by an ectodermal covering, which is in the same way the homologue of the endotheca in an ordinary gonophore, but here flattened out like the spadix, in accordance with the ribbon-shaped form of the gonophore.

b. *Multiplication by Fission.*

Kölliker* observed a process of true fissiparous multiplication in a medusa (*Stomobrachium mirabile*, Köll.) obtained in abundance at Messina. The fission always commenced by a vertical division of the manubrium, which thus became doubled; and this stage of the process was followed by a similar division of the umbrella, separating the animal into two independent halves. The process, however, did not stop here, but was followed by a further division of each of the two first-formed segments into two others, by a fission at right angles to the direction of the first; while Kölliker's observations led him still further to conclude that the process does not terminate with even the second cleavage, but, on the contrary, that it still goes on, the animal continuing to multiply itself by frequent acts of fission.

Developed generative bodies were not observed in *Stomobrachium mirabile*, and Kölliker is of opinion that this medusa is only the young of another (*Mesonema cærulescens*, Köll.) found in the same seas, and in which no division takes place, but in which well-developed generative sacs occur along the course of the radiating canals.

B. *Sexual Reproduction.—Generation.*

The origin and mode of formation of the ova and spermatozoa have already been considered; the phenomena presented by the development of the embryo now remain for discussion.

Development of the Embryo, from the commencement of the segmentation of the Vitellus to the attainment of the free locomotive stage.—I shall here describe this process as I have observed it in *Laomedea flexuosa*. In this species the gonophores, which belong to the adelocodonic class, are included within a gonangium, where they are borne along the whole length of a blastostyle, regularly increasing in maturity as they recede from the base towards the summit of their supporting column. Each gonophore in the female colony contains but a single ovum—a fact which facilitates the observation of the development.

The mature ovum (fig. 20 A), previous to the commencement of segmentation, is about 0·01 inch in diameter; it is of a granular structure, and contains a very distinct clear germinal vesicle about 0·002 of an inch in diameter, situated very excentrically, and easily separated from the surrounding vitellus, when it may be isolated as a perfectly spherical vesicle upon the stage of the microscope. There is occasionally a single germinal spot, but its place is usually taken by several (2 to 10) minute more or less spherical bodies, which float in the perfectly transparent and colourless fluid contents of the germinal vesicle. When the germinal vesicle is freed from the surrounding vitellus and floated in sea-water on the stage of the microscope, these bodies almost instantly disappear without leaving a trace behind, being apparently dissolved by water absorbed from without through the walls of the vesicle. If, however, a little tincture of iodine be previously added to the water, they continue visible, and are now plainly seen to be themselves vesicles, containing

* Zeit. f. wissen. Zool. 1853, p. 352.

within them a few minute granules which have been rendered obvious by the action of the iodine.

The vitellus is entirely composed of minute spherical corpuscles of apparently homogeneous structure, about 0·0002 of an inch in diameter, along with granules so small as not to admit of measurement. There is no obvious vitellary membrane in the mature ovum, but I have satisfied myself of its presence while the ovum is still in a very young state. In other species, *Hydractinia echinata* for example, this membrane is very obvious in the ovum just before segmentation. There is no trace of a micropyle in the ovum of this or of any other hydroid which I have examined.

There is never more than a single ovum in each gonophore of *Laomedea flexuosa*; and as this ovum continues to enlarge, it presses back the spadix until the latter is reduced to a small hollow projection in the bottom of the gonophore.

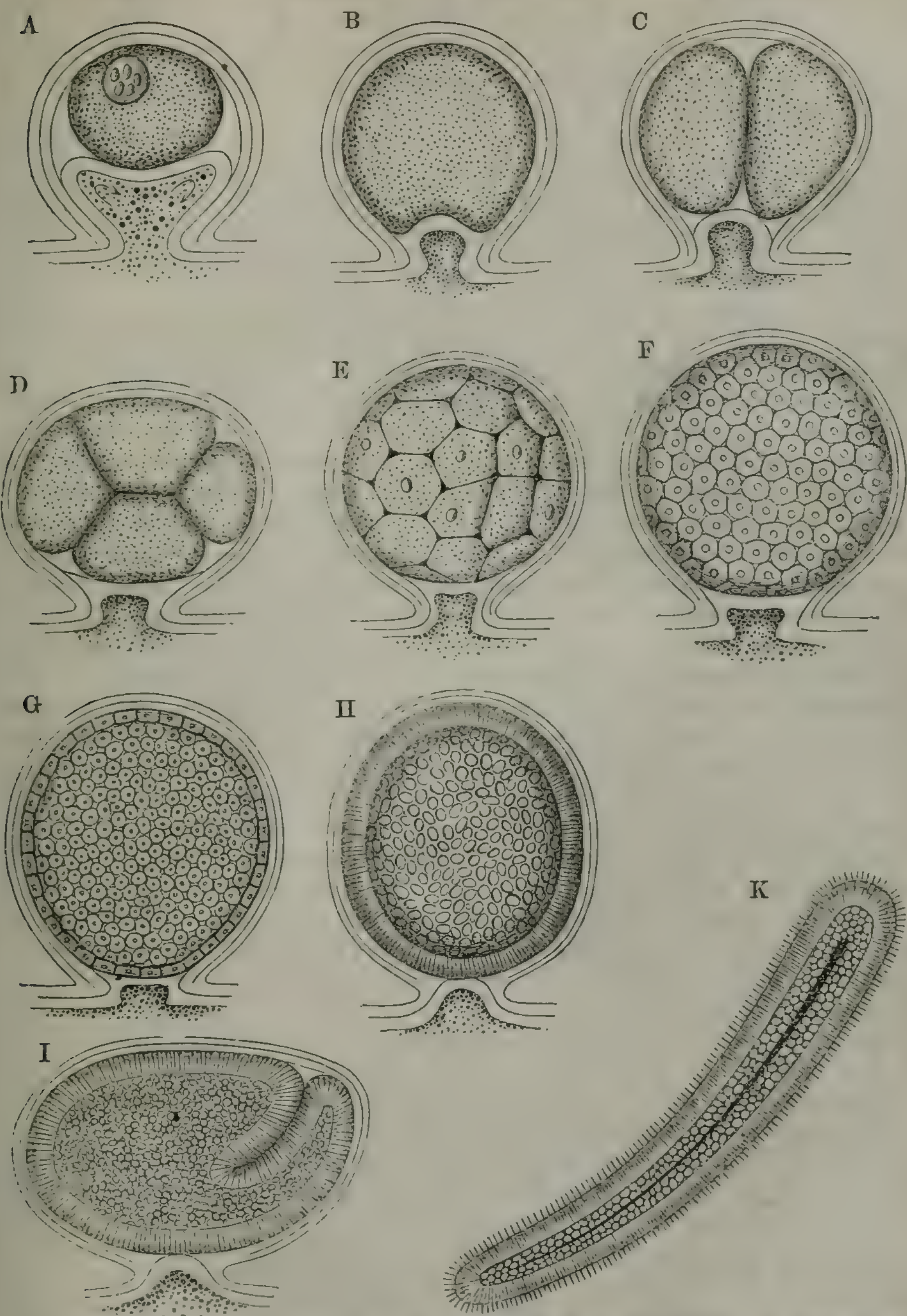
Up to this time the germinal vesicle continued quite distinct, but it now entirely disappears (fig. 20 B). The disappearance of the germinal vesicle is unaccompanied by any apparent change in the structure of the ovum, which retains the same peculiar composition of spherical corpuscles and granules. I have no doubt that the vesicle now ceases to exist, and that its disappearance is not due to its being merely concealed in the mass of the vitellus. It has probably burst, and in so doing must have liberated its peculiar contents, which will then of course be no longer visible in the vitellus. The disappearance of the germinal vesicle is probably the immediate result of impregnation; for I have seen active spermatozoa about this time in the cavity of the female gonophore.

It is useless to speculate upon the influence which the liberated contents of the germinal vesicle may exert in exciting the new series of phenomena which are now about to take place in the ovum; at all events, shortly after the disappearance of the germinal vesicle, the process of segmentation sets in. This process is certainly not preceded by the visible appearance of a new nucleus destined to take the place of the germinal vesicle. It is quite possible however that such a nucleus may exist, though, from its small size and from being so deeply imbedded in the mass of the vitellus, it may have eluded our attempts to discover it.

The first step observable in the segmentation-process is the cleavage of the yolk into two segments (fig. 20 C), immediately followed by the cleavage of these into other two, so that the vitellus is now composed of four cleavage-spheres (fig. 20 D). In none of them, however, can a nucleus be as yet demonstrated.

The segmentation would now appear to proceed very rapidly, but, perhaps, not always with absolute regularity; for it would seem occasionally to advance more rapidly in some of the previously formed spheres than in others. By the time that the vitellus presents about thirty-six or more cleavage-spheres (fig. 20 E) we begin to recognize in some of these spheres a distinct nucleus, while as the spheres become smaller and more numerous the nuclei become more and more apparent, until at last there may be seen in every minute sphere, of which the segmented yolk is composed, a brilliant nucleus, visible not only in the superficial spheres, but also in the deeper ones which come into view when the ovum is broken down under the compressor (fig. 20 F and G). It is therefore highly probable that in the earlier stages also a nucleus exists in every cleavage-sphere, but that in consequence of the thickness and opacity of the enveloping vitellus it is withdrawn from observation. The cleavage-spheres at this stage present the same peculiar structure which we find in the yolk just before the commencement of segmentation, consisting as they do of minute

Fig. 20.—Development of the ovum in *Laomedea flexuosa*.



A, young ovum in the gonophore previously to the disappearance of the germinal vesicle: the germinal vesicle is here seen to contain several germinal spots; B, the germinal vesicle and spots have disappeared; C, the vitellus has become cleft into two segmentation-spheres; D, the ovum after the second cleavage; E, the segmentation-spheres have become numerous, and many of them now show a distinct nucleus; F, the segmentation-spheres have greatly increased in number, and a nucleus may now be detected in each of them; G, the most superficial spheres have become arranged into a stratum distinguishable from the deeper portion of the ovum; H, the superficial stratum has become more distinct, and is now seen to be composed of long prismatic cells; I, the ovum has begun to elongate itself, and one end has become folded on the remainder; K, the embryo just after its escape in the form of a ciliated planula.

spherical corpuscles, with still more minute granules. When the vitellus has thus become broken up into a great number of minute spheres, it is evident that the most superficial of these spheres have arranged themselves into a distinct stratum, consisting of a single layer of spheres, and completely enveloping the more internal parts (fig. 20 G).

We next find that the spheres composing this layer have increased in number, while at the same time they have become longer in the direction of the radius of the ovum, and now form a rather thick layer of undoubled cells, arranged with their long axes perpendicular to the surface of the ovum, having their sides in close contact and investing, as with a continuous wall, the whole interior of the mass (fig. 20 H).

It is impossible not to see in the entire process here described an exact parallelism with the early stages in the development of the mammalian ovum, while the superficial layer of cells, to the formation of which we have just arrived, must be at once recognized as the representative of the blastoderm of the mammal*.

The nuclei, which were previously visible in the cleavage-spheres, have now ceased to be distinguishable, while these spheres at the same time show a distinct investing membrane. In fact, on now carefully breaking down the ovum under the microscope, its interior is found to consist entirely of loosely aggregated cells, some spherical, some more elongated, and all with a more or less copious endogenous brood of secondary cells within them (fig. 20 H).

The external enveloping layer having now attained a considerable thickness, and a well-defined differentiation between it and the more internal parts having been established, the ovum begins to elongate itself, and at the same time the interior has undergone a further change; for we no longer find in it the large mother cells with their endogenous brood, but a multitude of small, free, clear vesicles of various sizes mingled with the minute granules, which have all along formed a part of the constituents of the ovum.

At this point we may conveniently, though somewhat arbitrarily, designate the developing body as the "embryo." We find now that one end of the oval embryo begins to be prolonged beyond the rest, upon which it becomes bent back as it continues to elongate itself (fig. 20 I). By this time the embryo has become endowed with evident contractility, as manifested by sluggish changes of contour.

Shortly after this, the embryo escapes from its confinement by the rupture of the walls of the gonophore, when it speedily straightens itself and is discharged in the form of a long conical body through the summit of the gonangium into the surrounding water (fig. 20 K).

We now find that its whole surface is clothed with vibratile cilia, by whose aid it moves slowly along the bottom of the vessel, while the cells and granules which occupied its deepest parts seem to have undergone a kind of liquefaction, resulting in the formation of an elongated cavity in the axis of the embryo, which is thus, at that period, a nearly cylindrical sac, without, as yet, any appearance of a mouth, but with an endoderm and ectoderm already differentiated, while multitudes of very minute elongated-oval bodies, with a high refractive power, soon make their appearance in the ectoderm; these are most probably thread-cells, though no sign of a filament can as yet be discovered in them.

We have thus arrived at the ciliated and locomotive stage of the embryo.

* The comparison of the structure of the Hydrozoa to the early stages in the development of the highest animals has been very distinctly made by Professor Huxley (Oceanic Hydrozoa, p. 2).

To this stage Sir John G. Dalyell has given the name of "planula," a name, however, suggested by a mistaken view of its form, which he compares to a *Planaria*. In this comparison he has probably been led astray by the imperfection of the microscope employed; for the locomotive embryo has no tendency whatever to a flattened shape, as indicated by the name of "planula," but is always conical or cylindrical. Instead of "planula," therefore, one is strongly tempted to employ for this form of embryo some term which shall not tend to convey a false impression of its figure. The term "planula," however, has passed into such general use, and has, moreover, become so intimately associated with the memory of one to whose admirable and conscientious observations our knowledge of the Hydroida owes so much, that the defects of the term will hardly justify our suppression of it.

The further progress of the animal, up to that stage in which it has acquired all the essential features of the adult, admits of being easily traced in many different species. I shall take as a good type of the changes which the ciliated embryo undergoes in this progress the development of *Eudendrium racemosum*, Cav., in which I have satisfactorily followed the various steps.

After the embryo has enjoyed for a period (which, probably, extends over two or three days) its locomotive existence, it loses its cilia, and with them all power of active locomotion, though still apparently retaining the power of slowly creeping from place to place by the contractility of its body. It may now be occasionally seen with one end dilated, so as to give a flask-shaped form to the embryo.

We next find that the animal has attached itself to some fixed object by the enlarged extremity of its body, which becomes flattened over the surface to which it thus adheres. From the centre of this enlarged base the rest of the embryo rises perpendicularly as a little cylindrical or slightly clavate hollow column. The base now expands laterally, while, at the same time, it becomes compressed vertically, so as to acquire the condition of a little circular disc of adhesion. At the same time the embryo becomes enlarged a little behind its distal or free extremity by the formation of a slightly prominent circular ridge, while an exceedingly delicate periderm has been excreted as a scarcely perceptible film over its whole surface.

It will next be seen that a remarkable change has taken place in the disc of attachment by the division of this part into lobes separated from one another by radiating fissures, which commence as shallow notches at the circumference, and thence gradually increase in depth until they nearly reach the central vertical column. These lobes, like the rest of the young hydroid, consist of a layer of endoderm enveloped by one of ectoderm, while each contains a prolongation from the cavity of the column, and is invested by a delicate periderm, which may be traced into the bottom of the dividing fissures. The lobes of the disc increase in number by successive dichotomous division, though absolute regularity is not usually maintained.

In the mean time the young *Eudendrium* has increased in size, and the circular ridge has become more pronounced, while the part in front of this ridge has in the same proportion become more decidedly marked off from the rest of the body, and the periderm has here become more distinct by the partial withdrawal from it of the included structures.

Soon after this the whole circumference of the ridge will be found to have extended itself as a circle of about ten short, thick tentacula, while at some distance behind these the body is seen to be narrowed into a short, nearly cylindrical stem springing directly from the centre of the basal disc; and the more contracted portion which lies in front of the circle of rudimental tentacula

is now plainly recognizable as the proboscis or metastome of the future polypite. The tentacles now rapidly multiply by the intercalation of others between those already formed. The second set may at first be easily distinguished by their shortness; but the bases of all seem to be on the same level, and the whole appear to constitute a single uninterrupted series. The tentacles, though short and thick, will have thus soon attained the full number which we meet with in the adult. They consist in this stage of an endodermal and an ectodermal layer, the ectoderm apparently formed of a single layer of prismatic cells, while the endoderm seems to fill the entire axis with a mass of minute, spherical, loosely aggregated cells. Just behind the tentacles the body of the young polypite is seen to be excavated by a large cavity, in which is a multitude of loose spherical cells, filled with a red granular pigment, and undoubtedly thrown off from the inner surface of the walls.

The whole of the young hydroid is still completely enveloped by the delicate chitinous periderm, which forms a sheath extending over even the distal free extremity, and within which the various changes just described, including even the formation of the tentacles, have been going on. We now find, however, that this sheath (which has for some time lain loosely over the distal parts of the hydroid, and which it seemed to invest as in a sac) becomes ruptured in front of the tentacles, so that the water gains direct access to the surface of the young polypite, and the tentacles have full freedom to extend themselves. It would seem, too, that the distal extremity of the proboscis had now, for the first time, become perforated by a mouth; for, up to this stage, no undoubted evidence of an oral aperture could be detected.

The young *Eudendrium* has thus acquired the form of a true polypite borne on the extremity of a short simple cylindrical stem, which still springs from the centre of the radiating disc. The stem elongates itself, and the body, tentacles, and proboscis rapidly acquire all the characters of the adult; the hydroid, however, is still simple, and it remains for it to develope from its base a creeping stolon which will take the place of the primordial disc, to complicate itself by the budding of new polypites and the development of branches, and, finally, by the formation of sexual zooids to combine a gonosome with the primary trophosome, in order that the little hydroid whose progressive changes we have been thus following may attain the condition of the adult *Eudendrium*.

The developmental phenomena above described are in all their essential points, so far as we know, universal among the marine Hydroida, with one exception—that, namely, which is presented by the genus *Tubularia*.

In this genus a minutely granular plasma, entirely similar to that which in other Hydroida becomes differentiated into ordinary ova, may be seen enveloping the spadix of the young gonophore. Instead, however, of becoming transformed in the usual way into ova, portions become detached from the mass and lie loose in the cavity of the endotheca, where they undergo a development into free embryos in the manner to be presently described, while the residual plasma continues to detach from its mass fresh fragments, which are in their turn transformed into embryos.

In the portions thus successively detached from the central plasma it is impossible, as has already been said, to detect any trace of germinal vesicle or germinal spot, and yet we should certainly not be justified in regarding them as mere gemmæ, or in attributing to them any other significance than that of true ova *. The plasma in which they originate holds in the gono-

* Agassiz calls the central plasma in *Tubularia* the "germ-basis," and refuses to regard as ova the masses which are thrown off from it and become developed into polypoid young. (*Op. cit.* vol. iv. pp. 255 & 269.)

phores which contain it a position precisely similar to that held by the undoubted spermatogenous tissue in the male gonophores of the same species; and as nothing else is presented by the hydroid which can in any way be regarded as ova, we should, by denying to these the essential attributes of ova, be reduced to the anomalous alternative of admitting the existence of the male element without the correlative female one.

The phenomena connected with the development of *Tubularia indivisa*, in which I have carefully examined them *, will afford a good example of the difference between this form of development and that which is usual among the Hydroida; in all essential points they are the same as in the other species of *Tubularia*.

In the female gonophore of *Tubularia indivisa* (fig. 6 C), the generative product originates as a voluminous plasma between the endoderm and ectoderm of the manubrium. It is evidently in more intimate relation with the endoderm than with the ectoderm, and as it increases in bulk it would seem to cause the absorption of the latter membrane, which had confined it in its young state. A portion of it now becomes detached from the mass, and soon undergoes a special development into an embryo within the cavity of the gonophore. As has just been said, no trace of germinal vesicle or spot can be found either in the entire mass or in any of the detached portions; so also the phenomenon of yolk-cleavage, if present at all, is very obscure, but the detached mass may be easily broken up into cells filled with secondary cells.

The ovum (for I have no hesitation in so designating the mass detached from the primitive plasma, notwithstanding its anomalous characters) lies in contact with the remainder of the plasma, and while in this position becomes developed into an actiniform embryo, as has been already noticed by Van Beneden †, Mummery ‡, and others. In the act of development it becomes first extended as a disc over the residual plasma. In this disc we can always recognize a differentiation between its peripheral and central portions. Next, from the circumference of the disc short and thick processes radiate all round, and these soon elongate themselves into tentacles; the disc at the same time gradually becomes more gibbous on the side turned away from the axis of the gonophore, its interior becomes hollowed out into a digestive cavity, and a mouth makes its appearance in the centre of the opposite side, or that in contact with the plasma. The embryo now retreats from the plasma, the mouth is seen to be elevated on a conical prominence, while the side opposite to the mouth becomes more and more prolonged until it assumes the form of an elongated oval peduncle into which the general cavity is continued. The extremity of this prolongation presents the appearance of delicate striæ (probably fibres) radiating for a short distance from its central point—a peculiar structure which might easily lead to the belief that an aperture was here present. The appearance of an aperture, however, I believe to be entirely deceptive. At the same time a circle of very short tentacula makes its appearance immediately around the mouth. In this state it escapes from the gonophore, and, after continuing free for a period, the side opposite to the mouth becomes ultimately developed into a cylindrical stem, which soon clothes itself with a periderm and fixes the young *Tubularia* to some neighbouring object. After the escape of the embryo, or even during its develop-

* "Notes on the Hydroid Zoophytes," Ann. Nat. Hist. July 1859.

† "Recherches sur l'Embryogénie des Tubulaires," p. 37. pl. 1, in Nouv. Mém. de l'Acad. Roy. de Bruxelles, tom. xvii. 1844.

‡ "On the Development of *Tubularia indivisa*," Trans. Micr. Soc. 1853, p. 28.

ment within the gonophore, the remains of the plasma may still throw off portions which become developed in a similar way into free actiniform embryos*.

Our knowledge of the freshwater Hydræ is still in a very imperfect state, not only as regards the development of the embryo, but as to the structure of the parts on which the sexual functions devolve in these animals. Towards the end of autumn, and occasionally earlier, conical tubercles may be seen budding from the body of the various species of Hydræ, and containing, when mature, active caudate corpuscles. There is no difficulty in recognizing in these corpuscles spermatozoa, and in the containing tubercles true male gonophores,—a determination which we originally owe to Ehrenberg†. A minute aperture ultimately shows itself in the summit of the gonophore, and through this the spermatozoa escape.

But, besides the spermatogenous tubercles, there also occur, usually on the same individuals, others which, instead of containing spermatozoa, have their cavity occupied by a spherical body, first accurately described by Ehrenberg‡, and which, notwithstanding some anomalous features, we are justified in viewing as an ovum rather than anything else; while we must regard its containing sac as a female gonophore—a gonophore, however, in a very low stage of development, for the spadix is at an early period pushed back by the large single ovum, and remains undeveloped, while no ectotheca appears to be differentiated. In the male gonophore, on the contrary, the spadix is not suppressed, but may be seen projecting from the body of the hydra into the cavity of the gonophore. The ovum, when mature, escapes by the rupture of the walls of the gonophore, and is then seen to be invested by a tough membranous shell, which in some cases has been observed to develope peculiar forked spines over its entire surface. In this body, however, neither germinal vesicle nor spot has hitherto been detected; and, in the development from it of the embryo, the polypoid form appears to be directly attained, without the occurrence of a *planula*-stage§. The structure of the ovum and the developmental phenomena in *Hydra* would thus seem to come nearer to what we meet with in *Tubularia* than to the conditions presented by any other hydroid.

It will be thus seen that the earliest free stage of the HYDROID trophosome is locomotive, and shows itself under two distinct types—one pre-

* Claparède (Beobacht. über Anat. u. Entwickl. wirbelloser Thiere an der Küste von Normandie, 1863, p. 2) takes a somewhat different view of the development of *Tubularia* from that given above. His observations were made on certain minute organisms which he found swimming in the open sea, and which are undoubtedly the actinula-stage of some species of *Tubularia*. He compares them to small medusæ, the body of the actinula representing the umbrella, and the long tentacles the marginal tentacles of the medusa, while that portion which is subsequently to become developed into the stem of the *Tubularia* is viewed by Claparède as corresponding to the manubrium,—the mouth of the future *Tubularia*, with its circle of short tentacles, being developed on the summit of the umbrella. Claparède believes that he had found an aperture in the extremity of that portion which is to become the stem, and he has apparently thus been led to interpret this part as the manubrium of a medusa. I have little doubt that Claparède has been here deceived by the peculiar structure described above, and which might easily lead to an error of interpretation.

† Ehrenberg, Mittheilungen aus den Verhandl. der Gesellsch. naturf. Freunde in Berlin, 1838, p. 14.

‡ Ehrenberg, Abhandl. der Berl. Akademie, 1836, p. 115, taf. ii.

§ Pallas, Karakteristik der Thierpflanzen, p. 53. Laurent, Froriep's Neue Notizen, No. 513, p. 101; and 'Nouveaux Recherches sur les Hydres d'eau douce, Voyage de la Bonite,' 1844. See also "On the Generative System of *Hydra*," by Prof. Allen Thomson, *loc. cit.*, and Hancock, "Notes on a Species of *Hydra* found in the Northumberland Lakes," in the 'Annals of Natural History,' vol. v. 1850.

sented by the great majority of the HYDROIDA, and described above as the *Planula* of Sir J. G. Dalyell; the other confined to the genus *Tubularia*, unless *Hydra* also should afford an example of it, and which may be in the same way designated by the term *Actinula**. Every hydroid, if we except such forms as may be proved to pass to the medusal condition directly from the egg, thus commences its free existence either as a planula or an actinula.

Import of the Phanerocodonic Gonophore.—The developmental phenomena now described have been all observed in ova which have their origin in an adelocodonic gonophore; and they enable us to trace back the hydroid in an unbroken series, through the egg from which it is developed, and the gonophore in which this egg originates, to the hydroid trophosome from which the gonophore buds.

The cases in which a similarly unbroken chain can be traced back through the free phanerocodonic gonophore are naturally far less frequent; for in the majority of cases the free gonophore does not produce its generative elements until a considerable time after it has become free, and undergone more or less change of form as it continues to develope itself in the open sea; and it is very seldom that we can succeed in rearing the free medusæ in the confinement of our tanks up to the period when they shall attain sexual maturity†. We thus then almost always lose absolute evidence of identity in the gonophore when presented at two distant periods of its life; and there is, therefore, necessarily an interruption in the series of *direct* observations. Some such direct observations, however, have been made; and, besides these, so many facts have been ascertained by more or less discontinuous and fragmentary observations, that there remains no longer any doubt that the history of the phanerocodonic gonophores and their progeny is in all essential points identical with that of the adelocodonic forms.

Some cases have been observed in which the phanerocodonic gonophore has attained to complete maturity, and become loaded with ova or spermatozoa, before separating itself from the trophosome.

The first recorded instance of this phenomenon seems to be that described by Cavolini‡, who observed the medusiform zooids of his *Sertularia pennaria* (*Pennaria distycha*, Goldfuss) to become loaded with ova while still attached to the trophosome—an observation which about three-quarters of a century later was confirmed by McCrady§, who saw the ova in his *Pennaria tiarella* even become developed into planulæ before the detachment of the gonophore.

Rud. Wagner ‖ saw in a hydroid, which he names *Coryne aculeata*, the formation of buds, which became developed into somewhat arrested medusa-like gonophores; and then, before detaching themselves from the trophosome, gave origin to a copious brood of eggs in the walls of the manubrium.

Lovén¶ saw in a *Coryne*, which he refers to the *Syncoryne ramosa* of Ehrenberg, a medusoid body, also somewhat arrested in its development. It

* While the present Report was in the hands of the printer, I received a letter from Mr. Alder, in which he informs me that he has bred from the *Myriothela arctica* of Sars, free polypoid embryos closely resembling the free stage of *Tubularia*. From this important observation, it would follow that *Myriothela arctica* must also be placed among the hydroids which commence their free existence under the form of actinulæ.

† In the SIPHONOPHORA the opposite condition is prevalent; for here the gonophores, even such as present the more complete medusal or phanerocodonic form, usually become loaded with ova or spermatozoa before they detach themselves from the trophosome.

‡ Mem. Polypi Marini, 1785.

§ Proc. Elliott Soc. Nat. Hist. 1857.

‖ Isis, 1833, p. 256. tab. 11.

¶ Müller's Archiv, 1837, p. 321.

was produced upon the body of the polypite, and contained multitudes of ova, which had their origin in the walls of the manubrium. It is probable that the medusoid here described, though truly phanerocodonic, discharges its eggs without ever becoming free.

Wright observed in a *Coryne*, to which he gives the name of *C. gravata*, fixed medusiform bodies of the phanerocodonic type, with the spermatic mass largely developed in the walls of the manubrium*.

But the most complete observation of this class has been made by Agassiz†, who has seen in his *Coryne mirabilis* fully developed medusæ, referable to the type of *Sarsia*, originate as buds in the earlier months of the year, and then become free before any formation in them of ova or spermatozoa; while during the later months the same *Coryne* gives origin to medusa-buds which are arrested at a slightly less advanced stage of development, never become free, and produce in some cases ova, in others spermatozoa, in voluminous masses developed in the walls of the manubrium.

In all the above instances the generative elements had advanced far towards maturity, and the gonophore had apparently reached its final form while still attached to the trophosome. It will, I think, be found that, whenever this is the case, there is some degree of arrest in the complete medusal development, though not sufficient to reduce the gonophore to the condition of the adelocodonic forms. This shows itself especially in the tentacula, which usually remain in the state of mere tubercles, and, even when most developed, never attain the completeness and extensibility which characterize them in the free medusæ. It is also probable that in these cases the manubrium never developes a mouth at its extremity‡.

In other cases, however, the gonophores are detached, as free medusæ, in a much less mature state, in order to undergo further development in the open sea, and while yet the generative elements are quite rudimental, or even before any trace of them can be detected. Here, likewise, several cases have been recorded which prove, by direct and continuous observation, that these medusæ also have, as their proper function, the perpetuation of the species by true sexual generation.

The generative sacs which become developed upon the radiating canals of certain free medusæ were seen by Van Beneden § in the medusæ thrown off by *Laomedea dichotoma* ||. He mistook them, however, for nervous ganglia, an error which was afterwards rectified by Krohn¶; while similar bodies were subsequently observed, and correctly interpreted, by Kölliker** in a hydroid which he named *Campanularia dichotoma*, but which is certainly not the true *Campanularia* (*Laomedea*) *dichotoma*, whose medusæ are different from those described by Kölliker. Kölliker in this instance recognized the rudiments of the generative sacs even before the escape of the medusæ from the gonangium.

Gosse†† mentions and figures the generative sacs on the radiating canals of

* Edin. New. Phil. Journ. 1858, vol. vii. p. 282.

† *Op. cit.* vol. iv. p. 189.

‡ The gonophores of the Siphonophora also afford an example of the same phenomenon, in the fact that in most cases, even though attaining the phanerocodonic form, they stop short of the completely developed medusa, while at a very early period they develope the generative elements within them.

§ "Mém. sur les Campanulaires," p. 26. pl. 2. fig. 15, in Nouv. Mém. de l'Acad. Roy. de Brux. tom. xvii. 1844.

|| Named *Campanularia gelatinosa* in Van Beneden's memoir.

¶ Wiegm. Arch. 1851, p. 267.

** Zeit. f. w. Z. vol. iv. p. 301.

†† A Naturalist's Rambles on the Devonshire Coast, 1853, p. 303. pl. 19. fig. 3.

medusæ, which he saw liberated from the gonangium of *Campanularia Johnstoni*, Alder. He seems, however, not to have been aware of the nature of these bodies, which were afterwards observed in the same species, and correctly interpreted, by Wright *, who also witnessed the generative sacs on the radiating canals of the medusa of *Obelia* (*Laomedea*) *dichotoma* just after separation †.

I can fully confirm these observations on the medusa of *Campanularia Johnstoni*, having myself on more than one occasion witnessed the generative sacs budding from the radiating canals of medusæ shortly after liberation from the trophosome of this hydroid (see fig. 17).

In a Campanularian hydroid which I discovered in the Firth of Forth, and would refer to Van Beneden's genus *Campanulina*, under the name of *C. repens*, Allm., I found the generative sacs distinctly developed on the radiating canals of the medusa at the time of its liberation from the gonangium.

Dujardin ‡ has seen ova produced in the walls of the manubrium of *Cladonema*, a medusa traceable to a hydroid trophosome nearly allied to that of *Coryne*, and which Dujardin names *Stauridium* (Stauridie). These ova were observed in specimens of a *Cladonema* thrown off from *Stauridium* in his tanks, so that the observation is continuous and complete.

Krohn § has seen ova and spermatozoa produced in the walls of the manubrium of the female and male medusa-buds of a hydroid, which he believes to be identical with the *Podocoryne carnea* of Sars. The generative elements had indeed in this case made their appearance at a very early period, for their rudiments were manifest while the medusa was as yet incompletely developed, and still attached to the trophosome ‖.

To the facts above stated I am enabled to add the case of *Coryne eximia*, Allm., in whose medusa, just after liberation, from specimens obtained in Shetland in July 1862, I saw the generative mass in the form of a minutely granular substance included between the ectoderm and endoderm of the manubrium, and having nucleated spherical cells scattered through it. These cells are in all probability the germinal vesicles, with their germinal spot, but with the yolk not yet differentiated around them.

The cases now stated contain, I believe, the whole of the instances in which free medusæ, giving rise to ova or spermatozoa, have been traced by actual and continuous observation to the hydroid trophosome.

Evidence, however, scarcely less convincing, is afforded by those cases in which, though the free medusa in which the eggs or spermatozoa are found cannot be traced by *direct* observation to a trophosome, its resemblance to forms which have been so traced is so close as to justify us in assigning to both a similar origin.

Desor ¶ found, swimming freely in immense numbers in the port of Boston, United States, a *Sarsia*-like medusa, which he did not hesitate to identify specifically with a form which some weeks before he had seen produced by buds from a *Coryne* obtained in the same locality. In the free medusæ now obtained, the walls of the manubrium were swollen by the development in them of ova or spermatozoa. He was able to trace the ova through all the stages of segmentation.

* Edinb. New Phil. Journ. 1858, vol. vii. p. 286.

† *Op. cit.* 1859, vol. ix. p. 113.

‡ Ann. des Sci. Nat. 1845.

§ Wiegm. Arch. 1851, Erster Band, p. 263.

‖ In medusæ, however, thrown off from specimens of *Podocoryne carnea* in my tanks, no trace of generative elements could be detected, even at the end of fourteen days after their liberation.

¶ Ann. des Sci. Nat. vol. xii. 1849, p. 207.

I have myself frequently captured in various parts of the British seas a medusa which, except in its greater size (0·25 of an inch in diameter) and the increased number of its tentacles, so nearly resembles the medusæ which are thrown off from *Laomedea geniculata*, or the closely allied *L. dichotoma*, that I have no hesitation in referring it to one of these hydroids as its trophosome. The peculiar generative sacs (see fig. 18) were well developed near the middle of each of its radiating canals, and in some specimens contained mature ova, with germinal vesicle and spot, while in others they were filled with mature spermatozoa.

A similar observation was made by Krohn* on a little medusa which he captured in the Bay of Naples, and whose resemblance to the medusæ found by Van Beneden, as above stated, to be developed from *Laomedea dichotoma* was so close, that Krohn did not hesitate to regard it as the product of some similar trophosome.

Specimens of *Corymorpha nutans* obtained in the Frith of Forth, in the month of June, were kept alive for some weeks in my tanks. During this period multitudes of free medusæ were thrown off from them; but though the liberated medusæ continued to live for a considerable time, and increased slightly in size, they never developed any trace of generative elements. In the neighbourhood of the locality, however, which yielded the specimens of *Corymorpha*, I captured, by means of the towing-net, a small medusa, which I have little doubt belongs to the same species as those thrown off by the *Corymorpha* in my tanks. In the medusa thus found free in the open sea, the generative elements, though still immature, were very distinctly visible as a pale yellow mass between the ectoderm and endoderm of the manubrium, which was rendered tumid by their presence.

Besides the cases now enumerated, in which the sexually mature medusæ admit of being referred with certainty, or at least with high probability †, to specific trophosomes, there are the very numerous cases in which the generative elements have been detected in free gymnophthalmic medusæ whose trophosome is as yet unknown, or only a matter of suspicion ‡, and whose evidence in the present inquiry is necessarily only secondary and indirect.

I have thus endeavoured to bring together the whole of the evidence, which carries us up to a particular point in our investigations. This point is of great importance, for its determination enables us to enunciate the following general proposition:—

Many species of the fixed plant-like Hydroida give rise, by budding, to free gymnophthalmic medusæ, which ultimately attain, either directly (the gonocheme) *or indirectly* (the gonoblastocheme), *to sexual maturity, and produce ova or spermatozoa.*

But the point to which we have thus arrived does not complete the developmental history of the Hydroida, and the important question still remains, What is the result, immediate and remote, of the *development of the ovum produced by the free medusa?*

A considerable number of facts bearing upon this question have also been accumulated, and the development of the ovum has been traced with more or less minuteness by various observers, so that we are now enabled to present

* Wiegm. Arch. 1851, Erster Band, S. 265.

† It is possible for two medusæ to present no differences of even specific value, and yet be referable to specifically or even generically distinct trophosomes. (See below, p. 425.)

‡ See the various systematic treatises on the Medusæ, especially Forbes's 'Monograph of the British Naked-eyed Medusæ,' published by the Ray Society, 1848; Gegenbaur, "Versuch eines Systemes der Medusen," Zeitsch. f. wissen. Zool. 1857; and McCrady, "Gymnophthalmata of Charleston Harbour," Proc. of the Elliott Soc. of Charleston, South Carolina, 1859.

the terms which were still wanting to complete the life-series of the hydroid.

Krohn *, having placed in a jar of sea-water some mature specimens of *Cladonema* (a medusa which, as we have already seen, Dujardin had previously proved to be produced by budding from a *Coryne*-like trophosome, to which he gave the name of *Stauridium*), observed that after a time they had deposited eggs, which adhered to the sides and bottom of the vessel. Soon after deposition, the segmentation of the yolk commenced; and in about forty-eight hours after the beginning of the cleavage, the ovum had become changed into a free-swimming ciliated infusorium-like embryo (planula).

This embryo was successfully watched by Krohn through all its subsequent stages—the disappearance of its cilia, the fixing itself to the sides of the jar, its conversion into a little circular disc, the growth of a short column from the centre of the disc, and its final conversion into a hydroid, identical with the *Stauridium* from which Dujardin had originally seen the *Cladonema* thrown off. To Krohn then is due the first grand observation by which the whole circle of hydroid development, in the case of a free phanerocodonic gonophore, has been completed.

Gosse † had seen the medusa, *Turris neglecta*, Forbes, discharge from the generative mass formed in the walls of its manubrium ciliated planulæ, which, after some time, fixed themselves to the glass, and became elongated into adherent, branched, stolon-like bodies, which threw up a perpendicular stem, on whose summit a circle of four tentacles was developed, and the whole became thus changed into a *Clava*-like hydroid.

Wright ‡ subsequently watched the development of the ovum in this same medusa. His observations agree with those of Gosse, but he has succeeded in tracing the development a step further; for he saw the tentacles increase in number by the growth of others behind those first formed, giving by their scattered disposition a still more *Clava*-like appearance to the hydroid, while he also noticed the formation of a chitinous periderm which clothed the creeping stolon.

Gegenbaur § describes the development of the egg in a medusa, which he names *Lizzia Köllikeri*. He has seen the segmentation of the vitellus, and the formation of a ciliated planula, which, after enjoying for a time its locomotive existence, loses its cilia, fixes itself to the side of the vessel, expands one extremity into a disc of adhesion, elongates the rest of its body into a cylindrical stem, which, after clothing itself with a chitinous polypary, developes a mouth upon its free extremity, and just below this throws out a verticil of tentacula, while the expanded base becomes extended into short stolon-like prolongations.

The development of the ova in another medusa, named by Kölliker *Oceania armata*, was also observed by Gegenbaur ‖. He traced the segmentation of the vitellus, the formation of a ciliated planula, the fixation of the planula, and its development into a stolon-like body; but beyond this point his observations were not carried.

Wright ¶ observed that numerous planulæ had made their appearance in a vessel in which he had placed some isolated specimens of *Thaumantias inconspicua*. He believes that these planulæ were produced by the *Thau-*

* Müller's Archiv, 1853, p. 420. tab. xiii.
† A Naturalist's Rambles on the Devonshire Coast, 1853, p. 348. pl. 13.
‡ Edinb. New Phil. Journ. July 1859, pl. 8. f. 1.
§ Generationswechsel, 1854, p. 23. pl. ii. figs. 1–9.
‖ *Loc. cit.* p. 28. pl. 2. figs. 10–16.
¶ Micr. Journ. vol. ii., new ser.

mantias, and he saw some of them fix themselves to the sides of the vessel and develope a lobed disc. From this disc arose a stem, which developed from its summit a polypite closely resembling the *Campanularia raridentata* of Alder.

In the *Æquorea vitrina* of Gosse, Wright * also observed free ciliated planulæ to escape from the generative bodies, and, after fixing themselves to the sides of the vessel, become developed into a hydroid, with polypite, hydrotheca, and periderm, bearing, as he informs us, a close resemblance to the *Laomedea acuminata* of Alder.

The class of observations here enumerated enable us to complete the circle of hydroid-development; for they prove that the ova of the free medusa undergo, like those of the fixed gonophore, a continuous development, by which they become *transformed into polypoid trophosomes*; these trophosomes, as has been proved by direct observation in the case of *Stauridium*, and as we may unquestionably assume in other cases, giving origin, by buds, to medusæ identical with those from whose ova the trophosome was directly developed.

Relation between Sexual and Non-sexual Reproduction in the Hydroida.—The phenomena now described under the head of sexual and non-sexual reproduction present intimate and important relations with one another—relations which find their expression in the remarkable law, originally hinted at by Chamisso when he made his memorable discovery of the true genetic relations between the solitary *Salpæ* and the associated chain-like colonies of these animals, but first distinctly enunciated by Steenstrup, under the name of the "Alternation of Generations"—a law which, though in its original mode of statement it must undergo some modification, has nevertheless received, in all essential points, abundant confirmation, and will explain, in a way which it alone can do, a host of phenomena which would otherwise have appeared isolated and exceptional †.

The law in question manifests itself among the Hydroida in the fact that between every two sexual zooids one or more non-sexual zooids intervene, the *immediate* result of the development of the ovum being in such cases always a non-sexual form.

To take for example one of the simplest cases, we find that from the ovum of *Clava multicornis* there is developed directly a ciliated planula, passing by continuous metamorphosis into the non-sexual polypite. From this polypite there is then produced by gemmation a sexual zooid—the sporosac, which gives origin to ova or spermatozoa, destined to repeat the series, which thus consists of non-sexual polypite and sexual sporosac, and so on indefinitely.

The "period" here indefinitely repeated in the life of the species consists accordingly of two terms—polypite—sporosac.

Again, in *Hydractinia echinata* we have a case not quite so simple; for here, while the ovum becomes developed as before into a polypite, this polypite, instead of directly producing gonophore-buds, sends off from its basal extension or cœnosarc a peculiar bud, which, though still non-sexual, differs from the polypite, and has its alimentary functions suppressed. It constitutes the gonoblastidium, and is destined to give origin by budding to sporosacs.

* Micr. Journ. vol. iii. pl. 4. figs. 1–6.

† The true significance of the phenomena on which the law of "alternation of generations" has been founded was for the first time clearly pointed out by Dr. Carpenter. See Brit. and For. Med. Chir. Rev. vol. i. Jan. 1848, p. 183, &c.

In *Hydractinia echinata* then the period consists of three terms—polypite—gonoblastidium—sporosac.

A still further advance in complication is afforded by those forms in which a gonoblastocheme is developed, as in many of the *Campanularidæ*—*Campanularia Johnstoni* for example. Here we have polypite and gonoblastidium in the same order as in *Hydractinia*; but the gonoblastidium, instead of giving origin *directly* to sexual zooids, developes a new kind of zooid, as a bud from its sides, in the form of a non-sexual medusa or gonoblastocheme; and it is upon this gonoblastocheme that devolves the function of producing, by a process of gemmation, the ultimate sexual zooid in the form of a sporosac.

In *Campanularia Johnstoni*, therefore, the period will consist of four terms—polypite—gonoblastidium—blastocheme—sporosac.

It will be seen that, in the cases enumerated above, we have examples of three different types of alternation—the binary, the ternary, and the quaternary, this last presenting the highest order of complication which we know of among the HYDROIDA.

The three types may be conveniently formulated as follows:—

Binary. $\left.\right\}\ a\ b \quad a'\ b' \quad a''\ b'' \ \ldots\ldots\ldots$ &c.

Ternary. $\left.\right\}\ a\ b\ c \quad a'\ b'\ c' \quad a''\ b''\ c'' \ \ldots\ldots\ldots$ &c.

Quaternary. $\left.\right\}\ a\ b\ c\ d \quad a'\ b'\ c'\ d' \quad a''\ b''\ c''\ d'' \ \ldots\ldots\ldots$ &c.

Here every successive period is represented in the first series by two terms, in the second by three, and in the third by four; the "period" in each case repeating itself indefinitely like a circulating decimal, so as to represent in this repetition the indefinitely extended life of the *species*, while the life of the *individual* is expressed by each "period" singly.

It will be noted that the "terms" which, in the above formulæ, combine to form a period may each consist of many zooids. It is, in fact, very rare to find any term consisting of but one zooid. As an example of this latter condition, *Corymorpha nutans* may be adduced. In this hydroid, whose life-series belongs to the binary type, the polypite term, $a\ a'\ a''$, . . . &c., consists of a single zooid, while the gonophore term, $b\ b'\ b''$, . . . &c., may consist of a vast number of zooids,—the single polypite giving origin to numerous gonophores in the form of free medusa-buds. In almost every other case, however, the simple polypite becomes, by gemmation, a composite trophosome.

Direct Development of the Medusa from the Egg. Metamorphosis.—A question, however, of great importance still remains for discussion; for we have yet to determine whether the phenomenon of the so-called alternation of generations is a universal fact among the HYDROIDA, presented by every species in the course of its development.

In by far the majority of cases in which the development has been successfully traced, the life-series of the individual has presented a polypoid

non-sexual term intermediate between the ovum and the sexual medusal term.

Against the absolute universality of this law, however, certain observations have been adduced as tending to show that, in some cases, a direct development from the egg to the medusa takes place without the intervention of a non-sexual trophosome. Nevertheless a careful examination of those cases will render it evident that, with one sole exception, they afford no proof of the direct development of the medusa from the egg. As, however, the observations referred to present examples of a true metamorphosis, and are in other respects by no means without interest in the present inquiry, I shall here give an analysis of them, with the view of rendering apparent their real bearing and significance.

I shall first notice a set of observations which have been made upon certain medusæ belonging to the family of the *Æginidæ*—a group, however, with regard to whose exact systematic position there is some uncertainty, since in many of their characters they approach nearest to the true hydroid medusa, while in others they look towards the *Discophora*.

Whatever view we may be disposed to take of their nearest affinities, the *Æginidæ* possess so many points in common with the HYDROIDA, that the developmental phenomena observed among them can scarcely be overlooked in the present inquiry.

The first important observation bearing directly on this question is due to Joh. Müller*, who frequently captured, in the sea at Marseilles and Nice, a minute free-swimming hydroid. It was of an oval form, about half a line in its longer diameter, ciliated over its entire surface, with two tentacula-like processes near one end, and having at the opposite end an opening which led into a central cavity.

Müller considers this little animal to have been developed directly from the egg, and from its resemblance to a peculiar two-tentacled medusa which he obtained in considerable abundance at Nice, he believes himself justified in regarding it as one of the stages in the development of this medusa, into which he supposes it to pass by direct metamorphosis. He refers it to the genus *Æginopsis*, Brandt, and names it *Æginopsis Mediterranea*, Müll. Müller does not seem to have obtained any specimens of his *Æ. Mediterranea* so far advanced as to present traces of the generative elements; but his observations have been in this respect supplemented by Kölliker†, who afterwards obtained the same species at Messina in a sexually mature state.

Now we cannot overlook the fact that Müller has not, in the above case, traced his ciliated hydroid through a continuous series of developmental phases into the adult form of *Æginopsis*; and, without denying the probability that the ciliated bitentacular hydroid is really the larva of the *Æginopsis*, we cannot regard this relation as absolutely proved, while there is no evidence whatever that the ciliated form is the immediate result of the development of an ovum. Indeed, its remarkable resemblance to the singular generative zooid of *Dicoryne* (see above, p. 365) would seem to show the probability of another origin than that by direct development from the egg. Müller, led apparently by the analogy of the planula-stage of the *Hydroida*, considers the ciliated condition of the surface as affording evidence of such a direct development; but the fact that the *Dicoryne*-zooid is also richly ciliated over its whole surface shows that this argument goes for nothing.

* Müller's Archiv, 1851, p. 272.
† Zeit. f. wissen. Zool. vol. iv. p. 327.

A curious observation of importance in the present inquiry was made by Kölliker*, who found at Messina, in the stomach-cavity of a 10-tentacled medusa, evidently belonging to the family of the *Æginidæ*, and which he describes under the name of *Eurystoma rubiginosum*, Köll., a number of small organisms, resembling medusæ in various stages of development, and which he believed he could follow from stage to stage until he found them assume the form of a 16-tentacled medusa. To this last, which, as is evident from his description, also belongs to the family of the *Æginidæ*, he gives the name of *Stenogaster complanatus*, Köll.

The great difference between these two medusæ appears to Kölliker sufficient proof that the one could not have been produced by the other, and he regards the young Stenogasters as included accidentally in the stomach of the *Eurystoma*. He views, however, the young brood of *Stenogaster*, exhibiting as it does various steps in a metamorphosis, as affording evidence of the direct development of *Stenogaster* from the egg. It is, nevertheless, plain that there are no more valid grounds for such a conclusion in this instance than in Müller's case of *Æginopsis*.

Some very valuable observations bearing upon this subject have been made by M^cCrady† on another member of the *Æginidæ*. He observed lying free in the umbrella-cavity of one of the *Oceanidæ*, to which he gives the name of *Turritopsis nutricula*, M^cC., multitudes of little animals, presenting various forms, from that of a minute club-shaped hydroid to that of a well-developed medusa belonging to the type of the *Æginidæ*, and all undoubtedly connected with one another as stages of a simple developmental process.

Though he at first believed these to be the proper offspring of the *Turritopsis* in which they occurred, he afterwards rejected this notion, and recognized in them the young of a species of *Cunina* (*Cunina octonaria*, M^cC.), which had selected the umbrella-cavity of the Oceanidan in order to spend there as parasites the early stages of their existence.

M^cCrady views this case as presenting an instance of direct development from the ovum, believing that the *Cunina* originally gained access to the umbrella of the *Turritopsis* in the condition of a free-swimming planula. The untentaculated, club-shaped larva (the earliest stage observed) was followed by a bitentaculate hydroid form with long imperforate proboscis and distinct internal digestive cavity; and he noticed the interesting fact that this bitentacular stage freely repeats itself by budding. Next, two other tentacles make their appearance symmetrically between those first formed, while the extremity of the proboscis seems now to be perforated by a mouth. The umbrella next begins to make its appearance by an annular extension of the circumference of the body just below or at the oral side of the roots of the tentacles; and four new tentacles begin to sprout between those already formed, while lithocysts become developed on the margin of the incipient umbrella. After this the larva assumes the form of an adult *Cunina* in all essential points, except in the possession of a long proboscis, like that of a *Geryonia*, in which stage it leaves the umbrella-cavity of the *Turritopsis* to spend a free life in the surrounding water. It is only after it has quitted the medusa on which it had been hitherto living as a parasite that it loses its proboscis, and that the digestive cavity thereby assumes the form characteristic of the family of the *Æginidæ*.

M^cCrady's observations are made with great care, and the various steps in the transformation have been fully and satisfactorily traced; but still there

* Zeit. f wissen. Zool. 1843, p. 327.
† Proc. Elliott Soc. Nat. Hist. Charleston, 1856, p. 55.

is the same absence of evidence as to the origin of the earliest observed stage.

Now, so far from the three cases just detailed affording evidence of direct development from the egg, I believe that the evidence is altogether on the other side, and that we are more justified in regarding the earliest stage observed in each case as the immediate result of an act of gemmation, if not from a polypoid trophosome, at least from a previously existing medusa. The following three sets of observations made in this same family of the *Æginidæ* afford a clue to the true interpretation of the above-mentioned cases.

Gegenbaur* observed buds produced from the inner surface of the stomach-walls of a medusa, which he named at the time *Cunina prolifera*, though he afterwards referred it to the genus *Ægineta*, Gegenb.† He traced the development of these buds into a form closely resembling that of the parent medusa; they then become free in the surrounding water; and he does not seem to have followed them in their further progress.

Kefferstein and Ehlers‡ also observed buds proceed from the stomach-walls of a species of *Ægineta* (*Æ. gemmifera*, Keff. & Ehl.). They traced them through their development up to a point when they found them to acquire nearly the form of the parent medusa.

These two cases are thus instances of gemmation followed by metamorphosis, and render it probable that the developmental series observed by Johannes Müller, by Kölliker, and by M'Crady had their origin in a bud rather than in an ovum.

We have, however, a third case of especial interest in this inquiry, and one which seems to throw considerable light on the curious observation of Kölliker above mentioned, in which a brood of 16-tentacled medusæ was found in the stomach of a 10-tentacled form. The case to which I allude is recorded by Fritz Müller§, who describes the formation of ciliated buds from the internal surface of the stomach in an 8-tentacled *Cunina*, which he names *C. Kölikeri*, Fr. Müll. He traced these buds through various stages until he saw them detach themselves, and swim free in the cavity of the stomach. Here they underwent further development, which he continued to observe until he saw them transformed into true *Cuninæ*, differing, however, from the parent by the fact of their having twelve tentacles and twelve stomach-pouches instead of eight, the number characterizing the medusa which gave origin to them. Beyond this point Müller lost sight of them, and we are accordingly ignorant of their further changes and ultimate destination.

This case renders it highly probable that the 16-tentacled Stenogasters observed by Kölliker in the stomach of a 10-tentacled *Eurystoma* originated in an act of gemmation from the *Eurystoma*. M'Crady's case, however, where young *Cuninæ* were found in the umbrella-cavity of an Oceanidan, would seem to be one of true parasitism, the contained forms being here evidently in no way genetically related to the containing one.

The whole of the observations now detailed, beginning with that of Joh. Müller on *Æginopsis*, afford a valuable contribution to our knowledge of the life-history of the very aberrant group of medusæ which constitute the family of the *Æginidæ*. Some of them afford direct proof that in certain cases the medusæ of this family give origin to buds which detach themselves from the parent at a very early period of their existence and in a very imperfect condition, and then pass through a series of metamorphoses before arriving at

* Generationswechsel, p. 56. † Zeit. f. wissen. Zool. 1857, p. 202.
‡ Zoologische Beiträge in Neapel u. Messina, 1861. § Wiegmann's Archiv, 1861.

their adult state, while the phenomena presented by the other instances—those in which gemmation has not been directly observed—render it highly probable that the young forms seen in such instances are due also to an act of budding, followed, as in those cases where budding has been proved, by metamorphic changes; but whether in any of these cases the bud is destined to repeat exactly the parent form, or is only one term in a more extended life-series, we have not yet evidence to enable us to determine; while in no instance is there any proof whatever of the direct development of the medusa from the egg without the intervention of a non-sexual trophosome.

In two families of undoubted hydroid medusæ some observations have also been made, showing that the medusa passes during the free period of its existence through a series of well-marked metamorphoses before arriving at the adult state, resembling in this respect the *Æginidæ* whose metamorphoses have just been described.

Two such cases have been recorded. The first is one mentioned by Gegenbaur*, and adduced by him as a case of direct development from the egg. He describes a minute animal which he discovered swimming free in the sea. It was in shape somewhat like an inverted flask, measuring about 0·05 of a line in diameter, having the base of the neck surrounded by a circle of three or four short tentacles, with four minute lithocysts between them. The entire animal, even to the tips of the tentacles, was thickly clothed with fine cilia.

He traced it through various successive stages, in which he observed, first, an increase in the length and number of the tentacles; then the formation of an internal cavity, and a widening of the body into a more disc-like form, accompanied by an elongation of the neck; then the circumference of the disc-like body became extended laterally, and gradually assumed an umbrella shape, while the base of the internal cavity at the same time extended itself into eight radiating tubes, which, at the circumference of the disc, became united by a circular canal. It had thus assumed a complete medusa-form $\frac{1}{4}$ of a line in diameter; and we now find it with numerous rigid tentacula, eight radiating canals, lithocysts, and a two-lobed mouth; while the cilia have at the same time disappeared from the general surface of the body, remaining only on that of the tentacles, which appear to retain them through life. Gegenbaur refers his medusa to a new genus and species under the name of *Trachynema ciliata*, which he regards as the type of a distinct family not far removed from the *Eucopidæ*; but though he had met with specimens measuring 1 line in the diameter of the umbrella, he never witnessed in them the occurrence of sexual elements.

Here again, though an undoubted metamorphosis from a free-swimming ciliated form is apparent, there is no evidence whatever to show that the earliest observed stage had proceeded directly from the egg—a conclusion to which Gegenbaur seems to have been chiefly led by the ciliated condition of this stage. We have, however, already seen that a ciliated surface affords no proof of direct development from the egg.

The other case is one recorded by Fritz Müller†, who gives us an account of the metamorphosis of *Lyriope Catharinensis*, Fr. Müll., a medusa belonging to the family of the *Geryonidæ*. He obtained in the sea at Santa Catharina spherical transparent bodies from 0·2 to 0·3 mm. in diameter. In the interior of these was a spherical cavity, situated so excentrically that at one side it was separated from the external water only by a thin plate. He next observed

* Generationswechsel, p. 51.
† Wiegmann's Archiv, 1859, p. 310.

this plate to become perforated in the centre, while its contractions rendered it easily recognizable as a velum. Next, four tentacles began to sprout out from the circumference of the velum, and then four others between them, while a gastrovascular system, consisting of radiating and circular canals, had become visible, and the shallow manubrium might be seen in the bottom of the cavity. The first four tentacles were only temporary, being destined to disappear during the growth of the young medusa, while the second set remained as short rigid filaments. In the next place four other tentacles, long and eminently contractile, made their appearance, as permanent organs, near the bases of the temporary ones, while lithocysts had become developed near the bases of both the rigid and the contractile permanent tentacles. Finally, the manubrium elongated itself in the cavity of the umbrella, where it was itself borne on the extremity of a peduncle-like process from the roof; and the form of the adult *Lyriope Catharinensis*—the most abundant medusa of the surrounding seas—was thus ultimately attained.

Here, again, as indeed Müller himself admits, there is no evidence in favour of this being a case of direct development from the egg, the earliest stage observed having been found free in the sea, and certainly with none of the characteristics of an ovum; so that it is at least as likely that it should have been a free bud as a developing ovum.

Thus far then not a single recorded observation affords evidence that the gymnophthalmic medusæ ever originate directly by the development of an ovum. We have, however, one observation, and only one, in which the development of one of these medusæ has been traced backwards uninterruptedly to the egg and the parent medusa, without the intervention of any intermediate polypoid form.

For this important observation we are indebted to Claparède*, who obtained on the west coast of Scotland a species of *Lizzia* whose manubrium was loaded with eggs, some in an early stage, with the germinal vesicle and germinal spot still visible, while others contained an embryo in various stages of development. Similar ova, with the contained embryo, he also found floating free in the sea.

The embryo, while still confined within the vitellary membrane, presented all the features of a young medusa: from the centre of the bell-shaped umbrella there depended a thick-walled manubrium, whose cavity extended itself into four radiating gastrovascular canals, which ran in the substance of the umbrella, and opened at the margin into a circular canal, while round the margin were to be seen the rudiments of eight tentacula. Claparède's observations on the development of the embryo did not extend beyond this point; it is clear, however, that but slight changes were now needed to convert it into the form of the parent *Lizzia*.

VI. Heteromerism of the Individual.

From the facts now mentioned, it will be at once apparent that the Hydroida present to a most remarkable extent a phenomenon which may be described as the *heteromerism of the individual*. The term *individual*, in its proper zoological conception, must be understood in the sense so happily insisted on by Huxley, when he defined it as "the total result of the development of a single ovum"†. It is the true logical element of which the

* Zeit. f. wissen. Zool. 1860, p. 401.

† Huxley, "Report on the Researches of Professor Müller into the Anatomy and Development of the Echinoderms," Ann. and Mag. of Nat. Hist. July 1851; and "On Animal Individuality," *id*. June 1852.

species is composed, and a proper conception of its heteromerism is of vital importance in any attempt at the determination of affinities and a philosophical arrangement of species.

With scarcely an exception then, so far as we yet know, every hydroid consists at one period of its life of an assembly of zooids, and the true zoological individual is in reality the sum of all these zooids, whether they remain permanently associated or detach themselves from one another in order to become henceforth independent organisms.

This remarkable phenomenon may be termed the *Polymerism of the Individual.* But the peculiar characters of the hydroid individual do not stop with mere polymerism; the zooids composing it may, and, so far as our knowledge extends, always do present a greater or less amount of dissimilarity among each other, so that the individual is not merely *polymeric*, it is also *heteromeric*; and this distinction is of importance to be kept in mind; if we would form an adequate conception of the true hydroid individual*.

The extent to which heteromerism may be carried varies in different species. We may have the total result of the development of a single ovum composed of two different forms, or of three, or of four; in other words, the zooid elements whose sum constitutes the zoological individual may be *dimorphic, trimorphic*, or *tetramorphic*. *Clava, Coryne, Tubularia*, &c., present examples of dimorphism, the two forms here produced being the polypite and the gonophore. *Dicoryne* and most of the angiogonial hydroids afford examples of trimorphism—the gonoblastidium-form being in these cases added to those of the polypite and gonophore; while in *Laomedea dichotoma, Campanularia Johnstoni*, &c., we have instances of tetramorphism,—for in these hydroids the medusa which buds from the blastostyle properly remains sexless, giving rise by gemmation to the true sexual gonophore, which is in the form of a sporosac borne as a bud upon its radiating canals (see above, p. 401). *Hydractinia echinata* also affords among the gymnogonial hydroids a very interesting example of tetramorphism. In this hydroid the colony is composed of four different forms of zooids. 1. The ordinary nutritive polypites. 2. The gonoblastidia destined for the support of the gonophores: these may be morphologically regarded as polypites arrested in their development, the tentacles having become reduced to the condition of mere tubercles loaded with thread-cells, and the mouth remaining probably in most cases undeveloped, though it would seem to be occasionally present; they may be easily compared to the blastostyle of the angiogonial genera. 3. The gonophores or imperfectly developed and disguised medusæ. 4. A set of peculiarly modified polypites, which, like the ordinary polypites, properly belong to the trophosome; the tentacles have become aborted in them, being represented only by small hemispherical groups of

* The expression "heteromerism of the individual" is intended to convey nearly the same idea as Leuckart's "polymorphism of the individual" (see Leuckart, Ueber den Polymorphismus der Individuen, Giessen, 1851). The term "individual," however, is used by Leuckart for the separate zooids, which are, properly speaking, only the elements of which the zoological individual is composed; so that, with our present conception of an *individual* as the logical element of the *species*, the expression "polymorphism of the individual" would have a different meaning from that which Leuckart has assigned to it. I have therefore, instead of "polymorphism of the individual," used the phrase "heteromerism (ἕτερος, μέρος) of the individual," which easily conveys the intended meaning; while we may use that of "polymorphism of the zooids" to express the fact that the zooids are not all of the same form. The phrases "heteromerism of the individual" and "polymerism of the individual" may, it is true, be objected to on the grounds that they are self-contradictory; but this is the result of the new ideas which have become involved in our conception of the biological individual, which is no longer necessarily "*individuus*."

thread-cells, while the body has become much elongated and attenuated, and admits of being spontaneously thrown into convolutions twisted spirally in a plane at right angles to the common basis of the colony. This form occurs only at the extreme edge of the colony, close to the orifice of the univalve shell on which the hydroid has fixed itself.

Of the above four forms of zooids, it may however be doubted whether the long attenuated spiral polypites be not merely, notwithstanding their constancy, an abnormal departure from the normally developed polypite, due to the unfavourable conditions of constant attrition and other disturbances to which the colony is exposed at the extreme margin of the shell. I have indeed, at a little distance within the margin, met with forms intermediate between these and the ordinary polypites, being spirally twisted like the former, but having developed tentacles like the latter. Agassiz regards the spiral form as a modified reproductive polypite or gonoblastidium, but I cannot find that he has ever seen it bearing gonophores, while the intermediate form just mentioned seems to decide in favour of its belonging to the nutritive rather than to the reproductive zooids of the colony. According to Agassiz, the spiral polypites are occasionally branched in his *H. polyclina**.

Another remarkable example of tetramorphism is afforded by *Plumularia* and the allied genera, in all of which, besides polypite, gonoblastidium, and gonophore, we find entering into the composition of the colony the curious zooids to which the name of "nematophore" has been given, and which are described above. Here, indeed, *heteromerism*, as distinguished from mere *polymerism*, would seem to attain its maximum, the nematophores being formed upon a type which we have been hitherto in the habit of regarding as exclusively belonging to the Rhizopoda.

It will be at once perceived that the phenomena of heteromerism just described must be distinguished from the regular genetic succession of polymorphic terms involved in the conception of "alternation of generations;" for any one of the "terms" which combine to form a "period" (individual) in the life of the species (see above, p. 417) may be itself composed of heteromorphic zooids, without thereby altering the particular type of alternation, whether binary, ternary, or quaternary. Thus, while in *Hydractinia* the type of alternation is ternary, the type of heteromerism is quaternary.

I have already (see above, p. 359) referred to the impossibility of forming natural groups in any arrangement of the animals which form the subject of the present Report, without embracing the entire "hydrosoma;" and I have endeavoured to show that neither trophosome nor gonosome can of itself, as long as we are ignorant of the other, afford characters sufficient for the definition of any classificatory group.

As long as we admit the axiom that the species is composed of individuals, it is manifest that, unless the individual be known to us, we have not data for the definition of the species. Now for the conception of *individual* in its biological sense (the only one which in this question we have anything to do with) absolute organic continuity is not necessary, for the individual may be itself, as we now know, composed of zooids which are equally parts of it, whether they all remain in continuity with one another or become separate and

* Wright, who was the first to call attention to the spiral polypites of *Hydractinia*, also describes (Edin. Phil. Journ.) what he views as a distinct form of zooid, in the shape of long tapering filaments, occupying, like the spiral polypites, the extreme margin of the shell. These filaments, however, are certainly not constant, nor are they even usually present; and I do not hesitate to regard them as an abnormal state of the ordinary polypite, due to the unfavourable conditions to which it has become exposed.

independent organisms. Further, we know that in the hydroid individual we may not only have independence of zooids, but polymorphism of zooids; so that a knowledge of any one zooid-form may give us a totally inadequate conception of the true individual form. It is on this account that, before we can expect to construct classificatory groups upon a solid basis, we must determine the whole life-formula of the *individual*.

Now it must be admitted that the practical application of this principle is by no means free from difficulty, and that in those cases where the medusa detaches itself from the rest of the hydrosoma in order to lead an independent existence, the synthesis of the individual by the reassociation of its constituent zooids is often far from being an easy task.

One of the chief sources of this difficulty is found in the fact that the medusa at the time of its liberation has not yet attained its adult condition, and may still undergo great changes of form before arriving at maturity, while we necessarily lose sight of it in the interval, and can therefore, in most cases, only by inference identify the free-swimming adult medusa with the young form which we know to have originated in some definite trophosome.

But, besides this, numerous adult medusæ are known of whose trophosome we have not as yet any indication, though there can be scarcely a doubt that, like the others, the great majority of these have also their polypoid trophosome. It is plain that any attempt to arrange these medusæ into species and genera must be purely provisional—so much so indeed that we may have two medusæ between which it would be impossible to find specific differences, and yet their trophosomes may be widely different from one another, while, on the other hand, two very different medusæ may have trophosomes specifically indistinguishable.

In opposition however to this view, it has been asserted that similar trophosomes are always associated with similar medusæ. Thus Agassiz, finding the same form of medusæ—that, namely, which has been described under the generic appellation of *Sarsia*—originating from polypoid trophosomes which present no differences of generic value, and are accordingly included in our systems under a single generic name, that of *Coryne*, and finding, moreover, that this is the case in species gathered both upon the east and west shores of the Atlantic and upon the North American shores of the Pacific, concludes "that medusæ which are generically identical arise from hydroids bearing identical generic relations"*.

A little consideration, however, will show that this view is untenable; for a comprehensive survey of the HYDROIDA has distinctly proved that the amount of divergence between two different trophosomes is by no means a certain measure of the divergence between their gonosomes.

If we were to imagine for a moment that a phanerocodonic and an adelocodonic gonophore were independent organisms, instead of being mere zooids associated with others in a complex hydrosoma, we should not hesitate to regard the differences between them as of at least generic value, and yet we may have the trophosomes from which these two forms of gonophore respectively spring presenting no differences which would justify us in regarding them as more widely separated from one another than two species of a common genus. We need only compare the *Laomedea flexuosa*, for example, and its simple fixed sac-like gonophores, with the *Laomedea geniculata* and its free disc-shaped medusæ, in order to be convinced how widely the gonosomes may differ, and yet the trophosomes present no difference of importance.

* Agassiz, Nat. Hist. of the United States, vol. iv. p. 217.

But, to convince ourselves of this difference, it is not necessary to include in our comparison the fixed sac-like gonophores at all; for if we confine ourselves to those cases in which the comparison lies between free medusæ on the one hand and the trophosomes from which they spring on the other, we shall still find that the doctrine which would always refer similar medusæ to similar trophosomes, and similar trophosomes to similar medusæ, though in a large proportion of cases it holds good, cannot be absolutely maintained.

On this point we have an important observation made by Hincks, who found the medusæ produced by the *Stauridia producta*, Wright, indistinguishable from those of *Coryne eximia*, Allm., and yet the two trophosomes have justly been regarded as presenting generic differences.

Again, we are not without cases of the converse of this phenomenon, that is, cases of trophosomes closely resembling one another, and yet producing widely different medusæ. Compare in this respect the *Coryne eximia*, Allm., and the *Coryne implexa*, Alder. No one would venture, from a comparison of the trophosomes alone, to place these hydroids in different genera; and yet their medusæ are separated from one another by characters which, if we were treating organisms originally independent, would be regarded as at least generic; for while the medusa of *Coryne eximia* would, in accordance with the received classification, be an *Oceania**, that of *C. implexa* would be a *Zanclea*, Gegenb.

Far more rare than the cases in which known medusæ have not yet been referred to known trophosomes are those in which the gonosomes of known trophosomes have not yet been discovered; and even these will rapidly disappear under the laborious scrutiny to which the whole of this department of zoology is now being subjected. Until this happens, however, our characterization of species cannot be otherwise than incomplete; for no such group can be valid which is founded only on one part of every individual composing it, the other part remaining unknown.

An Account of Meteorological and Physical Observations in Five Balloon Ascents in the year 1863 (*in continuation of eight made in the preceding year*), *under the auspices of the Committee of the British Association for the Advancement of Science, by* James Glaisher, *F.R.S., at the request of the Committee, consisting of Colonel Sykes, the Astronomer Royal, Lord Wrottesley, Sir D. Brewster, Sir J. Herschel, Dr. Lloyd, Admiral FitzRoy, Dr. Lee, Dr. Robinson, Mr. Gassiot, Mr. Glaisher, Prof. Tyndall, Dr. Fairbairn, and Dr. W. A. Miller.*

The principal efforts of the Committee in this series were the extension of the experiments began last year to the spring months, and particularly during the prevalence of easterly winds.

§ 1. Objects of the Experiments: Instruments and Apparatus: Were the same as those detailed in the preceding Report; in addition, however, Sir John Herschel's actinometer was used when possible for the purpose of determining the actinic effects of the sun at different elevations; and on two or three occasions the solar spectrum was examined by means of a spectroscope, lent for the purpose by the Astronomer Royal, being the same in-

* In the sense in which this genus has been limited by Forbes.

strument used by Professor Smyth on the Peak of Teneriffe, but somewhat altered by Mr. Simms to adapt it to the limited space in the balloon.

§ 2. Observing Arrangements

Were in principle the same as those of the preceding year, the only alterations made being those necessitated by the use of new instruments.

Circumstances of the Ascents, and General Observations.

The ascents were all made by Mr. Coxwell's large balloon, as in the preceding year,—four from the Crystal Palace, Sydenham, and one from Wolverton.

Ascent from the Crystal Palace, March 31.—The day was favourable, the wind was from the East, in gentle motion, the sky was blue and almost cloudless. We left the earth at $4^h\ 16^m$ P.M., and passed upwards with a very nearly even motion to the height of 19,000 feet; continued about this level for some little time, and then gradually ascended to a height of 24,000 feet, which we attained at $5^h\ 28^m$, or in $1^h\ 12^m$ after starting. On opening the valve, though it seemed to be but momentary, we descended $1\frac{1}{4}$ mile in 4 minutes; this rapid descent was checked by parting with sand, and for half an hour we kept very nearly upon a level, between 15,000 and 16,000 feet high; after this we gradually and almost continually declined, and reached the earth at $6^h\ 26^m$, the descent having been accomplished in 58 minutes.

The temperature of the air was 50° on the ground, and the air was more nearly in a normal state than I had ever before seen it; almost every successive reading of the thermometer was less than the preceding in ascending, and greater on descending; the departures from these necessary conditions in a normal state were very small on this occasion. The temperature was just zero at its highest point, and 42° on the ground. There had, therefore, on the earth been a decline of 8° during the $2^h\ 10^m$ we were away; and if the numbers on the same level be compared, it will be seen that all those when descending are lower than those ascending, indicating that the whole mass of air was declining in temperature as that in immediate contact with the earth, though possibly to a less degree.

Almost free as this day was from disturbing causes, yet there existed both warm and cold currents of air.

The temperature of each layer of air was different according to its direction of motion, and there were several different currents met with. Within 2 miles of the earth the wind was East, between 2 and 3 miles high it was directly opposite, viz., West; about 3 miles it was N.E., higher still it changed to the opposite, viz., S.W., and about 4 miles, including the highest point, it was W.

On descending, at $6^h\ 15^m$ we fell into a S.E. current, and moved towards London.

When nearly 4 miles high we traced the smoke from a furnace chimney, moving towards the West; after a time it turned more towards the East, then changed its direction two or three times, and finally followed us on our level.

At the greatest height the sky was of the deepest Prussian blue, the streets of London could be picked out as lines, and the squares could easily be seen, having all the appearance of an engineer's plan.

The river wound like a serpent; passing the eye down it, ships looked like little boats to beyond the Medway, where they were lost; the white cliffs of Margate were plainly seen; the sea beyond Deal and Dover was visible, but not the French coast. The coast-line was seen passing down the northern side of the Thames to Harwich and up to Yarmouth, with the sea beyond.

Mr. Coxwell said he could see Ipswich. Looking South, Brighton was visible, the sea beyond, and all up to Dover; the North was obscured by clouds and mist. The West was not as clear as the East, but the sun shone on the Thames at Windsor, giving it the appearance of burnished gold.

At Putney the rippling of the water at its edges was like molten silver, and all the country within these limits was map-like, every field being distinct in the suburbs of London, gradually diminishing in size as the distance from London increased. Greenwich Park was visible, the Observatory apparently a grey speck. We touched the ground at 6^h 30^m in a field belonging to Mr. G. Brown, Gaysthorn Hall, Barking Side, Essex.

Ascent from the Crystal Palace, April 18.—The balloon was partially filled during the evening of April 17, with the view of starting early the following morning. The atmosphere was at this time thick and misty; the wind on the earth was N.E., but pilot balloons, on attaining a moderate elevation, fell into a north current; the wind was moving at an estimated velocity of 40 miles an hour, and the ascent was delayed hour after hour in hopes that the upper current would change to N.E.

At 1^h p.m., when the sky was nearly covered with clouds and there were occasional gleams of sunshine, the ascent was decided upon, although it was evident it could not be one of long duration, unless the wind should change its direction, or we crossed the Channel; Mr. Coxwell did not, however, think it prudent to attempt the latter without other and special arrangements: whilst discussing this, the rope, our only connecting-link with the earth, broke, and at 1^h 17^m we started very unceremoniously, the balloon taking a lurch: Mr. Coxwell was partly jerked over the side of the car, and I was thrown among my instruments, and unfortunately both Daniell's and Regnault's hygrometers were broken. Within 3 minutes we were more than 3000 feet high; at 4000 feet cumulus clouds were on our level, and a thick mist rested everywhere on the earth. At 1^h 26^m we were 7000 feet high, in a thick mist which almost amounted to a fog; the temperature of the air continued at 32° nearly, whilst that of the dew-point increased several degrees; on passing out of the cloud these two temperatures very suddenly separated, the latter decreasing rapidly; the sky was of a deep blue, without a cloud on its surface.

At 1^h 30^m we were 10,000 feet high; directly under us was a sea of clouds; the towers of the Crystal Palace were visible, and by them we found we were moving South. The temperature before starting was 61°; it decreased to 32° on reaching the cloud, and continued at this reading whilst in it, then suddenly fell to $23\frac{1}{4}$° on leaving the cloud, and was either less or the same at every successive reading till we reached the height of 20,000 feet, when the lowest temperature was noticed.

On passing above 4 miles the temperature increased to $14\frac{1}{4}$°, and then declined to $12\frac{1}{4}$° at the highest point, viz. 24,000 feet, in 1 hour and 13 minutes after starting. When we were just 4 miles high, on descending, Mr. Coxwell began to reflect that possibly we might have been moving more quickly than we expected, and that it was necessary to descend till we could see the earth; he opened the valve rather freely at 2^h 34^m, and we descended a mile in 3 minutes; we descended quickly but less rapidly through the next mile, and reached the clouds at 12,000 feet from the earth at 2^h 42^m; on breaking through them at 2^h 44^m, still 10,000 feet from the earth, I was busy with my instruments, when I heard Mr. Coxwell exclaim, "What's that?" he had caught sight of Beachey Head. I looked over the car and the sea seemed to be under us. Mr. Coxwell again exclaimed, "There is not a moment to spare, we must save the land at all risks; leave the instruments." Mr.

Coxwell almost hung to the valve-line, telling me to do the same, and not to mind cutting my hand. It was a bold decision, and was boldly carried out.

When a mile high the earth seemed to be quickly coming up to us, and we struck the ground at $2^h\ 48^m$ at Newhaven, very near the sea; but the balloon, by the very free use of the valve-line, was so crippled, that it did not move afterwards. Nearly all the instruments were broken, and, to my great regret, three very delicate and beautiful thermometers, specially sent to me for these observations by M. A. D'Abbadie, were broken.

Ascent from the North-Western Railway Works at Wolverton, June 26.—In this ascent the Directors of the North-Western Railway provided the gas, and gave every facility to Members of the Committee of the British Association and their friends to be present.

The gasometers at Wolverton are too small to hold gas enough to fill the balloon, it was therefore partially inflated the night before, and remained out all night without being influenced by the slightest wind; the morning of the ascent was also calm; the sky was of a deep blue, implying the presence of but little vapour; the atmosphere was bright and clear, and all circumstances were of the most promising kind. The time of ascent was fixed to take place some little time after the express train from London should arrive, or at a little after noon, and the completion of the filling was somewhat delayed, the extraordinary fineness of the morning promising its completion in a short time. Between 11 and 12 o'clock all these favourable circumstances changed; the sky became covered with clouds, some of them of a stormy character, the wind rose and blew strongly, the balloon lurched a great deal: much difficulty was experienced in passing the gas into the balloon, and sufficient could not be passed in by 1 o'clock. The wind was momentarily increasing, and it became very desirable to be away.

The greatest difficulty was experienced in fixing the instruments, which would have been broken but for Mr. Negretti, who had come from London to assist me, and who protected them even at the hazard of being hurt by the violent swaying of the balloon and the incessant striking of the car upon the ground, notwithstanding the united exertions of many men to hold it.

At the time of leaving the spring catch was jammed so tight by the pressure of the wind that it would not act, and we were let free by the simultaneous yielding of the men, and had to part instantly with ballast to avoid striking adjacent buildings.

It was 3^m after 1^h p.m. when we left the earth, with a strong W.S.W. wind. The temperature was 65°. In 4 minutes we were 4000 feet high, and entered a cloud with a temperature of 50°, experiencing a most painful feeling of cold, particularly Mr. Coxwell, who at the moment of leaving was overheated from his great exertions, and owing to his anxiety about the change in the weather had left without any extra clothing. As on all previous occasions, we expected soon to break through the clouds into a flood of strong sunlight, with a beautiful blue sky, without a cloud above us, and with seas of rocky clouds below; but, on the contrary, when we emerged all looked dark both above and below; we could see the earth, but it was dark and dull, and without colour; above us there were clouds. At 9000 feet high we were both struck with a sighing, or rather moaning of the wind, such as precedes a storm; it was the first time that either Mr. Coxwell or myself had ever heard such a sound in the air. We satisfied ourselves that it was in no way attributable to any movement of the cordage about the balloon, but that it was owing to conflicting currents of air beneath. At this time we saw the sun very faintly, and momentarily expected its brilliancy to increase; but instead of this, although we were now 2 miles high, we entered a fog, losing entirely

the sight of the sun; shortly afterwards fine rain fell upon us. We then entered a dry fog, passed out of it at 12,000 feet, saw the sun again faintly for a short time, and then entered a wetting fog.

At 15,000 feet we were still in fog, but it was not so wetting; at 16,000 feet we entered a dry fog; at 17,000 feet saw faint gleams of the sun, and heard a train. We were now about 3 miles high; at this time we were not in cloud, but clouds were below us; others on our level at a distance, and yet more above us. We looked with astonishment at each other, and said as we were rising steadily, we surely must soon pass through them. At 17,500 feet we were again enveloped in fog, which became wetting at 18,500 feet; we left this cloud below at 19,600 feet. . At 20,000 feet the sun was just visible. We were now approaching 4 miles high; dense clouds were still above us; for a space of 2000 to 3000 feet we met with no fog, but on passing above 4 miles our attention was first attracted to a dark mass of cloud, and then to another on our level; both these clouds had fringed edges, they were both nimbi. Without the slightest doubt both these dark clouds were regular rain-clouds; whilst looking at them we again lost sight of everything, being enveloped in fog whilst passing upwards through 1000 feet. At 22,000 feet we again emerged, and were above clouds on passing above 23,000 feet. At 6 minutes to 2 o'clock we heard a railway-train; the temperature here was 18°. I wished still to ascend to find the limits of this vapour, but Mr. Coxwell said we are "too short of sand, I cannot go higher; we must not even stop here." I was therefore most reluctantly compelled to abandon the wish, and looked searchingly around. At this highest point, in close proximity to us, were rain-clouds; below us dense fog. I was again reminded that we must not stop. With a hasty glance everywhere, above, below, around, I saw the sky nearly covered with dark clouds of a stratus character, with cirri still higher, and small spaces of blue sky between them; the blue was not the blue of 4 or 5 miles high as I had always before seen it, but a faint blue, as seen from the earth when the air is charged with moisture.

Hastily glancing over the whole scene, there were no extensive, fine or picturesque views, as in such situations I had always before seen. The visible area was limited; the atmosphere was murky, the clouds were confused, and the aspect everywhere dull. I cannot avoid expressing the surprise I have felt at the extraordinary power which a situation like this calls forth, when a few moments only can be devoted to note down all appearances and all circumstances, and if not so rapidly gleaned they are lost for ever. Under such circumstances, every appearance of the most trivial kind is noticed; the eye seems to become keener, the brain more active, and every sense increased in power to meet the necessities of the case; and when we look back after the lapse of time, it is wonderful how distinctly at any moment scenes so witnessed can be recalled, and made to reappear mentally in all their details.

We then began our downward journey, wondering whether we should meet the same phenomena; soon we were enveloped in fog, but passed below it when at 22,000 feet, and saw the sun faintly. At 20,000 feet we were in a wetting fog and passed beneath it at 19,500 feet, experiencing great chilliness; fog was then above and below. I now wished to ascend into the fog again, to check the accuracy of my readings as to its temperature, and the reality of the chill we had felt, so we reascended. The temperature rose to its previous reading, and fell again on descending. From the same level, for a thousand feet, we passed down through a thick atmosphere, but not in cloud or fog. Looking below, all was dark and disturbed; looking upwards, not much better. At the height of 18,000 feet we were again in fog. At 3 miles high we were still in fog, and on passing just below 3 miles

rain fell pattering on the balloon. This was 1 mile higher than we experienced rain on the ascent, and it was much heavier. On passing below 14,000 feet we entered a snow-storm, and for a space of nearly 5000 feet we passed through a beautiful scene. There were no flakes in the air, the snow was entirely composed of spiculæ of ice, of cross spiculæ at angles of 60° and 90°, and an innumerable number of snow-crystals, small in size but distinct, and of well-known forms, easily recognizable as they fell and remained on the coat. This unexpected circumstance of snow on a summer afternoon was all that was needed on this occasion to complete the experience of extreme heat of summer with the cold of winter within the range of a few hours. On passing below the snow, which we did when about 10,000 feet from the earth, we entered a murky atmosphere, which continued till we reached the ground; indeed so thick, misty, and murky was the lower atmosphere, that although we passed nearly over Ely Cathedral, and not far from it, we were unable to see it. When 5000 feet high we were without sand, and became simply a falling body, checked by the dexterity of Mr. Coxwell in throwing the lower part of the balloon into the shape of a parachute.

The place of descent was in a field on the borders of the counties of Cambridge and Norfolk, 20 miles from the mouth of the Wash and 8 miles from Ely.

Ascent from the Crystal Palace, July 11.—This ascent was intended to have been one of extreme height, and the promise of success in this respect was held out until near the time of starting, as pilot balloons had passed nearly due east, and indicated that our course would have been towards Devonshire, but so doubtful is the course a balloon will take that no certainty can be felt till the balloon has actually left. However, on this occasion pilot balloons, though at first moving towards the west, soon met with a north wind and went south. Under these circumstances the attempt to ascend five miles was abandoned, and we resolved to ascertain, as far as possible, the thickness of the stratum influenced by the east wind, to profit by the knowledge and have as long a journey as we could.

At the time of leaving, $4^h\ 55^m$ P.M., the sky was nearly covered with cirrus and cirrostratus clouds, and the wind was blowing due east. In about 4 minutes, and when at the height of about 2400 feet, the balloon suddenly changed from moving towards the west to moving due south. At 8 minutes past 5 we were over Croydon, at the height of 4600 feet, in mist, but could see the Green Man Hotel, Blackheath; we then descended, passing downwards through a thick atmosphere, till at $5^h\ 32^m$ we were 2200 feet high over Epsom Downs, and again within the influence of the east wind. We then turned to ascend, and at $5^h\ 52^m$ were 3000 feet above Reigate; here we could see Shooter's Hill and the Crystal Palace, by the two towers of which we found we were again within the influence of a north wind. We then continued to ascend, with the view of ascertaining if we could pass above the north wind; at $6^h\ 16^m$, when at 5400 feet, the wind shifted to N.N.W. and the atmosphere became very thick and misty, the sun's place being just visible. At $6^h\ 28^m$ we were 6600 feet high, and the sun was wholly obscured; we descended somewhat, but did not get below the mist. At $6^h\ 40^m$ we were 6200 feet high and directly over Horsham.

We then ascended to 6600 feet again to repeat the observations I had made, and found that the temperature in the half hour had declined 2° or 3°. At this time, $6^h\ 56^m$, cirri and cirrostratus were very much higher than ourselves, and we saw the coast near Brighton.

A consultation had been held whilst at this height with the view of crossing over to France, but our progress being so slow and the circumstances not

promising success, we came down with the view of again falling into the east wind, supposing it still to be prevalent. We met the north wind again at about 5000 feet, and the east wind at exactly the same height, viz. 2400 feet, at which we lost it on ascending. We descended to within 1000 feet of the earth and were near Worthing, at about 5 miles from the coast; we then ascended to 2700 feet, found ourselves moving towards the coast, and within the influence of a north wind; evidently, therefore, if we wished to continue our journey we must keep below 2400 feet, otherwise we should be blown out to sea. When again at the height of 2400 feet we turned to move parallel to the coast, being at this time over Arundel. Sheep in the fields were evidently very frightened, and they huddled together. We now descended to 800 feet, and thus journeyed at heights varying from 800 to 1600 feet; villagers frequently shouting to us to come down, and now and then answering our questions as to the locality we were in. The cheering cry of children was frequently heard above other sounds. Geese, cackling and frightened, scuttled off to their farms. Pheasants crowed as they were going to roost; and as we approached the end of our journey packs of dogs barked in the wildest state of excitement at the balloon.

Thus journeying, all motion seemed transferred to the landscape itself, which appeared when looking one way to be rising and coming toward us, and when looking the other sinking and receding from us. It was charmingly varied with parks, mansions, white roads, and in fact all the constituents of a rural scene of extremely beautiful character. The place of descent was Goodwood Park, the seat of the Duke of Richmond.

Ascent from the Crystal Palace, July 21.—The weather on this day was bad, the sky overcast and rainy. Although in every respect a thoroughly bad day, it was well suited to investigate, if possible, some points concerning the formation of rain in the clouds themselves; to determine why a much larger amount of rain is collected in a gauge near the surface of the earth, than in one placed at an elevation in the same locality; whether during rain the air is saturated completely, or if not, to what extent; to discover the regulating causes of a rainfall sometimes occurring in large drops, at others in minute particles.

So long back as the years 1842 and 1843 I made many experiments in order to ascertain why so great a difference in volume was found to exist in the water collected at lower stations as compared with that collected at higher. The experiments which yielded the best results were those in relation to temperature. I always found that when the rain was warm, with respect to the temperature of the air at the time, no difference existed in the quantities of rain collected at different heights; but when the temperature of the rain was lower than the temperature of the air, a considerable difference always existed.

From this circumstance, it would appear probable that the difference in the quantities of rain collected at different heights is owing (at least in part) to the great condensation of the vapour in the lower atmosphere, through being in contact with the relatively cold rain.

It was also desirable to confirm, or otherwise, Mr. Green's deductions; this gentleman believing that, whenever a fall of rain happens from an overcast sky, there will invariably be found to exist another stratum of cloud at a certain elevation above the first. We left the earth at 4^h 52^m p.m., and in 10 seconds had ascended into the mist; in 20 seconds to a level with the clouds, but not through them. At the height of 1200 feet we passed out of this rain and overlooked a range of surrounding clouds, so dazzlingly white that it was with difficulty I could read the instruments furnished with ivory scales. At the

height of 2800 feet we emerged from clouds and saw a stratum of darker cloud above; we then descended to 800 feet over the West India Docks, and saw rain falling heavily upon the earth. None was falling upon the balloon; that which we saw, therefore, had its origin within 800 feet of the ground; we ascended again, and this time passed upwards through fog 1400 feet in thickness. At 3300 feet we passed out of cloud, and again saw the dark stratum at a distance above; clouds obscured the earth below. On descending, at 2700 feet we entered a dry fog, but it became wetting 100 feet lower down. After passing through 600 feet the clouds became more and more wetting, and below were intensely black. At $5^h\ 28^m$ we were about 700 feet high, or about 500 feet above Epping Forest, and heard the noise of the rain pattering upon the trees. Again we ascended to 2000 feet, and then descended, passing into squalls of rain and wind at the height of 500 feet, with rain-drops increasing in size as we descended, till they were as large as a fourpenny piece, on reaching the ground being of the same size as when we left it. On descending we found rain had been falling heavily all the time we were in the air.

§ 3. Description of the Table of Observations.

All the meteorological observations taken during the ascents are contained in Table I.

Column 1 contains the times at which the observations were made. Column 2 contains observations of the siphon barometer corrected for temperature and index error. Column 3 contains the readings of the thermometer attached to the barometer. Column 4 contains the readings of an aneroid barometer. Column 5 contains the height above the level of the sea, as deduced from the barometric observations in column 2, by the formula of Baily, checked at intervals by that of Laplace, which is as follows:—

$$Z=\log\left(\frac{h}{h'}\right)\times 60159\left(1+\frac{t+t'-64}{900}\right)\left(1+0\cdot002837\cos 2\,\mathrm{L}\right)\left(1+\frac{z+52251}{20886900}\right),$$

where Z is the height required, and h, h', t and t' the height of the barometer corrected for temperature, and the temperature of the air at the lower and upper stations respectively, L the latitude. The temperature of the air for the position of the balloon has been derived from the readings in column 10. Columns 6 to 9 contain the observations with the dry- and wet-bulb thermometers free, and the deduced dew-point. Column 10 contains the readings of Negretti and Zambra's gridiron thermometer. Columns 11 to 14 contain the observations with the dry- and wet-bulb thermometers aspirated, and the deduced dew-point. Columns 15 and 16 contain the direct dew-point observations with Daniell's and Regnault's hygrometers. When numbers are entered in columns 15 and 16 with "no dew" affixed to them, it is meant that the temperature of the hygrometer has been lowered to the degree stated, but that no dew has been deposited.

The Astronomer Royal at the Royal Observatory, Greenwich, had meteorological observations taken every 10 minutes on all the days of ascent, and Dr. Lee had observations made at Wolverton by his assistant, Mr. S. Horton, with instruments furnished and adjusted by Mr. Negretti, on June 26.

In calculating the height of the balloon, the observations of Greenwich have been employed for March 31, April 18, July 11, and July 21; and those of Wolverton for June 26.

The height of Greenwich above the mean sea-level=159 feet.

The height of Wolverton above the mean sea-level=300 feet.

TABLE I.—Meteorological Observations made in the Ninth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	4 7 0 p.m.	29·75	......	29·93	......	49·8	44·2
(2)	4 10 0 ,,	29·72	......	......	......	49·8	44·2
(3)	4 11 0 ,,	29·72	......	......	420	49·8	44·2
	4 14 0 ,,	29·72	......	29·75	420	49·2	44·2
(4)	4 16 0 ,,	29·39	......	......	780	48·0	41·8
	4 17 0 ,,	29·10	48·0	......	1,048	47·2	40·8
	4 18 0 ,,	28·60	48·0	......	1,515	46·0	38·1
	4 20 0 ,,						
	4 20 30 ,,	......	......	......	.. ...	......	......
	4 21 0 ,,	26·56	46·0	......	3,507	37·5	33·0
(5)	4 21 30 ,,	26·36	......	26·38	3,698	38·5	32·0
	4 23 0 ,,	25·31	45·0	25·35	4,771	37·0	30·0
(6)	4 24 0 ,,	24·82	44·0	......	5,296	35·5	29·2
	4 25 0 ,,	24·22	......	......	5,937	35·1	26·1
(7)	4 27 0 ,,	23·52	41·5	......	6,251	33·2	26·0
	4 27 30 ,,	23·22	41·0	......	7,035	33·0	25·1
	4 28 0 ,,	22·92	40·5	......	7,380	32·6	24·9
(8)	4 29 0 ,,	22·75	40·0	......	7,557	32·1	24·8
(9)	4 32 0 ,,	21·63	......	......	8,872	28·5	(30·0)
(10)	4 33 0 ,,	21·33	38·0	......	9,218		
	4 35 0 ,,	20·63	38·0	20·58	10,047	26·2	19·1
(11)	4 39 0 ,,						
	4 40 0 ,,	18·73	......	......	12,536	......	......
(12)	4 41 0 ,,	18·33	......	18·23	13,070	19·1	10·1
(13)	4 42 0 ,,						
	4 43 0 ,,	17·34	......	......	14,481	15·1	6·1
	4 44 0 ,,	16·84	33·0	16·93	15,198	14·2	5·1
	4 44 30 ,,	16·49	31·0	......	15,738	12·2	4·2
(14)	4 45 0 ,,	......	......	......	(15,793)	12·2	4·0
(15)	4 46 30 ,,	15·95	29·5	......	16,669	11·1	5·2
	4 46 45 ,,						
(16)	4 47 0 ,,	......	......	15·63	17,060	9·0	2·0
(17)	4 48 0 ,,	15·45	30·0	......	17,451	9·0	3·0
(18)	4 49 0 ,,	15·35	28·0	15·33	17,616	8·5	3·0
(19)	4 49 30 ,,	14·86	26·0	......	18,475		
(20)	4 50 0 ,,	14·96	25·0	......	18,304	11·1	7·2
	4 51 0 ,,	15·06	22·0	15·03	18,123	11·0	7·1
	1.	2.	3.	4.	5.	6.	7.

NOTES AND GENERAL

(1) Detached cumuli; blue sky; misty.
(2) Blue sky.
(3) Blue sky.
(4) Passing top of tower of Crystal Palace.
(5) Very misty.

(6) London beautiful; Isle of Dogs visible at an apparent distance of one mile; a few fine cumuli clouds, apparently resting on the ground.

(7) Regnault's Hygrometer is very troublesome; I cannot get dew deposited on the cup. The earth appears to be dotted with cumuli clouds; blue lines of light are crossing each other at right angles.

(8) Very beautiful deep blue sky. Spectrum is very bright; less lines both at red and violet ends; G is quite the limit, and I cannot see to B; C is doubtful.

(9) Colours of the spectrum are very bright.

(10) The sea is visible to the south of us; London is a wonderful sight; sun shining over the Thames at Windsor, which looks like burnished gold.

Balloon Ascent, from the Crystal Palace, March 31, 1863.

mometers (free.)		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
5·6	38·3	......	......	......	......	......	38·0	
5·6	38·3	49·8						
5·6	38·3	......	......	......	......	......	......	36·2
5·0	38·9							
6·2	35·0	47·1						
6·4	33·7							
7·9	29·2	43·0	......	......	......	......	......	30·0
......	......	38·6						
4·5	26·8							
6·5	23·3							
7·0	20·1	36·6						
6·3	19·5	35·5						
9·0	11·7	33·5						
7·2	11·6						[no dew.	
7·9	9·3	......	......	......	......	......	22·0	
7·7	8·2							
7·3	7·9							
7·1	−16·9	28·5	......	......	......	......	......	[no dew. 20·0
......	......	16·1						[no dew.
9·0	−55·0	......	......	......	......	......	......	1·0
9·0	−63·6	11·0						
9·1	−63·5							
8·0	−58·0	9·5						
8·2	−58·0	9·0						
5·9	−40·7	13·2						
7·0	−52·4							
6·0	−43·6	10·5						
5·5	−39·7	10·3						
3·9	−23·2	11·1						
3·9	−23·4	11·1						
8.	9	10.	11.	12.	13.	14.	15.	16.

REMARKS.

(11) Can see to line F in the spectrum; violet dull; cannot see a single line beyond D.
(12) Valve opened; gas very thick.
(13) Lost sight of the violet end of the spectrum; cannot see any lines at all.
(14) Spectrum very short; no lines; can see a little beyond D to E, not F.
(15) My heart beats very loud; the sun's shape in the water is well defined; Isle of Dogs visible; St. Katherine's Docks very distinct, apparently 10 miles distant; Crystal Palace apparently nearly under us.
(16) Gas issuing from the neck of the balloon. (17) Gas yellow and opaque.
(18) No lines visible in the spectrum, faint violet rays to G; my face is of a glowing purple.
(19) Letting gas off rapidly; the earth looks beautiful.
(20) Mouth of the Thames apparently nearly under us; coast visible to Dover; can see Brighton and the sea beyond; gas suddenly became clear.

TABLE I.—Meteorological Observations made in the Ninth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	4 52 0 p.m.	15·46	23·0	......	17,400	......	......
(2)	4 58 30 "	15·67	......	......	17,097	12·1	9·1
(3)	4 59 30 "	15·67	......	......	17,097		
	5 2 0 "	15·36	20·0	15·23	17,636	11·0	8·0
(4)	5 4 0 "	14·96	20·0	14·93	18,293	10·5	6·0
	5 6 0 "	14·66	......	14·53	18,730	9·3	2·5
	5 6 30 "	14·62	17·5	......	18,795	8·2	2·0
(5)	5 7 0 "	......	......	......	......	7·0	2·5
(6)	5 8 50 "	14·37	17·0	13·93	19,197		
(7)	5 10 0 "	14·27	19·0	14·03	19,356	3·0	−0·5
(8)	5 12 0 "	13·47	......	13·43	20,865		
	5 14 0 "	13·87	......	13·83	20,076		
	5 15 0 "	13·82	......	......	20,136		
(9)	5 16 0 "	13·68	......	13·24	20,374	2·0	−0·5
	5 17 0 "	......	......	13·10			
	5 20 0 "	13·18	11·0	......	21,331	2·0	−0·1
(10)	5 23 0 "	13·48	......	......	20,749		
(11)	5 24 0 "	13·38	......	13·33	20,910	2·0	−2·0
(12)	5 25 0 "	12·88	10·0	......	21,868	1·5	−2·5
(13)	5 26 0 "	12·78	......	......	22,068		
	5 27 0 "	12·38	10·0	......	22,884	1·0	−4·0
(14)	5 31 0 "	15·98	......	......	16,486	3·2	......
	5 32 0 "	16·09	......	......	16,309	4·1	
(15)	5 33 0 "	15·78	......	......	16,809		
(16)	5 34 0 "	16·83	......	......	15,149	7·5	
	5 35 0 "	16·88	......	......	15,080	8·2	
(17)	5 37 0 "	16·88	......	......	15,080		
(18)	5 38 0 "	16·58	13·0	16·43	15,556	11·1	9·1
(19)	5 41 0 "	16·57	16·1	16·33	15,565	9·1	6·2
(20)	5 42 0 "	16·37	15·5	......	15,872	9·3	5·1
(21)	5 42 30 "	16·47	15·0	......	15,714	9·1	5·2
(22)	5 43 0 "	......	......	16·13	16,080	9·1	5·1
(23)	5 45 0 "	......	......	16·13	16,080	9·1	5·1
(24)	5 46 0 "	16·17	......	16·13	16,080	8·0	5·1
	5 47 0 "	16·17	......	16·13	16,080		
(25)	5 47 40 "	16·17	......	......	16,080	7·2	3·1
(26)	5 49 0 "	16·37	......	......	15,847	7·2	3·1
	5 50 0 "	......	......	......	(15,775)	7·2	3·1
(27)	5 50 30 "	......	......	......	......	......	......
	1.	2.	3.	4.	5.	6.	7.

(1) Just over the Isle of Dogs; moving S.W.; changed our course; temperature increased suddenly; Royal Observatory visible; Green Man Hotel, Blackheath, distinct; horizon not visible; mass of clouds to the N.W. so distinct that the boundary line can be traced; can see the rippling of the river below Putney Bridge.

(2) We shall cross the Thames.

(3) In a S.W. current; temperature beginning to decline; face very blue; feet very cold.

(4) Over Isle of Dogs. (5) Let gas out by opening valve.

(6) Over Victoria Docks; cold intense; hands very cold.

(7) Let gas out again; no spectrum.

(8) Nearly westerly current; Lowe's ozone powder deeply coloured.

(9) I could not get dew on Regnault's Hygrometer, and I failed to get its readings below −10. (10) No spectrum.

(11) Had to break ice for water; over Thames; breathing deeply.

(12) Hands blue; Thames looks beautiful.

Balloon Ascent, from the Crystal Palace, March 31, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	.....	11·2						
3·0	−14·2							
3·0	−15·3	12·1						
4·5	−29·0	11·0						
6·8	−50·3	7·5						
6·2	−46·0	7·5						
4·5	−32·6	7·0						
3·5	−28·7	4·5						
2·5	−20·6	1·0						
2·1	−16·8							
4·0	−33·9	0·5						
4·0	−34·9							
5·0	−35·4	0·0	......	......	......	......	less than −10·0	
......	......	3·1						
2·0	− 6·4							
2·9	− 6·3	8·5						
4·2	−27·5							
3·9	−35·1	8·2						
4·0	−26·0							
4·0	−26·0							
2·9	− 7·4	8·0	......	......	......	......	less than −10·0	
4·1	−28·7							
4·1	−28·7							
4·1	−28·7							
......	......	......	(3·5)	(−6·0)				
8.	9.	10.	11.	12.	13.	14.	15.	16.

(13) Mouth of Thames visible; coast clear to Yarmouth.
(14) Mr. Coxwell's pulsations 98, mine 97 per minute.
(15) Smoke from chimney up to us going N.E.
(16) The river Thames visible almost from its source to the sea; and the adjacent country quite clear.
(17) It is a curious sight to see the little spiral lines of steam from trains on Tilbury line, Romford, and Chelmsford; between Barking and Romford.
(18) Smoke up and almost level with us. (19) Dropped pencil over the car.
(20) Regnault's Hygrometer does not act. (21) In a westerly current.
(22) No spectrum. (23) Chelmsford in sight. (24) East coast clear; Ipswich in sight.
(25) Very cold (tried vibrations of magnet, but failed).
(26) Could not get magnet to vibrate.
(27) Lowered grapnel; doubtless the large mass of iron not very distant from the magnet had exercised a good deal of influence over it.

TABLE I.—Meteorological Observations made in the Ninth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	5 51 0 p.m.	......	......	......	......	......	......
	5 52 0 „	16·47	......	......	15,630	7·0	3·0
(1)	5 52 30 „	16·57	......	16·13	15,489		
	5 53 0 „	16·77	......	16·33	15,227		
	5 54 0 „	16·97	13·0	16·73	14,965	7·0	6·0
(2)	5 55 0 „	17·17	......	16·83	14,622	7·0	
	5 56 0 „	17·37	......	......	14,325	8·5	7·0
	5 56 30 „	17·37	15·0	17·18	14,325	9·0	7·0
(3)	5 57 0 „	17·88	15·0	17·83	13,614	10·8	7·1
(4)	5 57 30 „						
	5 58 0 „	18·27	......	......	13,077	11·5	8·2
(5)	5 58 30 „	18·47	15·0	18·33	12,797	12·2	10·1
	5 59 0 „	18·87	15·5	......	12,232		
(6)	6 0 0 „						
	6 1 0 „	19·28	......	......	11,674	13·5	11·1
(7)	6 2 0 „	19·47	15·0	19·33	11,486	14·5	11·2
(8)	6 3 0 „	19·87	......	......	10,917		
(9)	6 5 0 „	20·97	......	......	9,570	18·5	13·1
(10)	6 8 0 „	22·38	......	22·33	7,907	21·2	17·0
(11)	6 9 0 „	22·78	......	22·73	7,443	21·5	
	6 9 30 „	......	......	......	(7,050)	22·2	18·0
	6 10 0 „	23·48	16·0	23·43	6,657	23·0	19·5
	6 10 30 „	......	......	......	......	......	......
	6 11 0 „	......	......	23·78	6,279	24·2	20·5
	6 11 30 „	24·18	17·0	24·13	5,901	24·8	21·0
	6 12 0 „	24·38	......	......	5,696	25·1	21·2
(12)	6 13 0 „	24·77	......	......	5,273	25·5	22·0
(13)	6 14 0 „	......	......	......	(4,910)	25·9	22·0
	6 14 30 „	25·29	19·0	25·23	4,729	26·0	22·0
(14)	6 15 0 „	25·57	19·0	25·53	4,441	27·8	23·0
	6 16 0 „	25·87	......	25·83	5,168		
(15)	6 17 0 „	26·48	21·0	26·43	3,528	28·2	24·4
	6 19 0 „	26·87	......	......	3,143	28·5	26·1
	6 20 0 „	27·07	22·0	27·03	2,950	29·5	26·2
	6 21 0 „	27·46	......	27·38	2,570	30·0	27·2
	6 22 0 „	27·96	24·0	......	1,908	30·0	27·5
	6 22 30 „	28·16	......	......	1,724	30·9	27·5
(16)	6 23 0 „	28·36	25·0	28·33	1,590	31·5	28·0
(17)	6 24 0 „	28·86	......	......	1,260	32·2	28·5
	6 25 0 „	29·06	24·0	......	1,070	32·8	29·0
(18)	6 25 30 „	29·50	......	......	893	35·0	
(19)	6 30 0 „	......	......	29·89	ground	42·0	
	1.	2.	3.	4.	5.	6.	7.

(1) Darkness creeping over the earth. (2) Ground looks dark, and the sky very bright.
(3) Gas very clear. (4) Heard some sounds from the earth.
(5) No spectrum; not sufficient light. All the observations to-day were made on sky spectra; I could not get a sun spectrum.
(6) Mr. Coxwell's hands felt as if they were scalded; he could not lower grapnel by himself.
(7) Mr. Coxwell called me to his assistance to help him to lower the grapnel.
(8) Heard railway-train. (9) Violent retching. (10) Feeling of illness.
(11) Vomiting. (12) Over Romford. (13) Over railway-station.

Balloon Ascent, from the Crystal Palace, March 31, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	......	... ..	......	......	......	less than −10	no dew −10
4·0	−28·1							
1·0	− 1·8							
1·5	− 4·6	8·5	......	......	......	......	−10·0	
2·0	− 8·5							
3·7	−21·5							
3·3	−17·4	12·0						
2·1	− 6·2							
2·4	− 7·5	11·5						
3·3	−14·4	12·0						
5·4	−26·9	19·0						
4·2	−11·8	21·5	......	......	......	......	−10·0	
4·2	− 9·7							
3·5	− 2·4							
......	......	26·0						
3·7	− 1·3							
3·8	0·0	......	......	......	......	......	0·0	
3·9	+ 9·7	27·0						
3·5	3·5							
3·9	2·2							
4·0	1·7	27·8						
4·8	3·3	28·5						
3·8	13·9	30·0						
2·4	16·9	30·0						
3·3	15·1	31·0						
2·8	18·4							
2·5	19·7							
3·4	18·4							
3·5	19·9							
3·7	20·0							
3·8	20·4							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(14) Fallen in with S.E. current; over Ilford Jail. At this time we fell into another current and changed our course again; moving back.

(15) Ozone 8.

(16) Sand out.

(17) Over Romford or Ilford.

(18) Packed up in a hurry.

(19) Touched the ground at $6^h\ 30^m$, at sunset, in a field belonging to Mr. G. Brown, Gaystham Hall, Barking Side, Essex, having first been caught in a tree, then broke through it; a number of rude countrymen came, and by some means the balloon was much injured.

TABLE I.—Meteorological Observations made in the Tenth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	0 12 0 p.m.	......	......	29·80	......	61·0	55·2
	0 15 0 ,,	......	......	29·80	......	59·5	53·5
	1 13 0 ,,	29·66	61·0	29·83	......	60·8	54·5
	1 14 0 ,,	29·66	61·0	......	......	61·5	54·2
(2)	1 16 0 ,,						
(3)	1 17−0 ,,	29·17	60·5	......	1,030	59·2	54·0
	1 17+0 ,,	28·57	60·5	28·75	1,603	57·2	51·1
	1 18 0 ,,	27·97	60·0	......	2,185	56·0	50·5
	1 18 30 ,,	......	......	......	(2,380)	55·2	49·0
(4)	1 19 0 ,,	27·57	60·0	27·75	2,575	54·0	48·0
(5)	1 20 0 ,,	......	......	26·75	3,555	49·2	43·0
(6)	1 21 0 ,,						
(7)	1 21 10 ,,	25·79	55·0	25·75	4,392	47·2	41·0
(8)	1 22 30 ,,	24·50	51·5	24·75	5,759	41·2	35·1
	1 24 0 ,,	......	......	......	......	40·5	37·0
(9)	1 24 15 ,,	23·90	49·0	......	6,420	39·0	
	1 24 30 ,,	23·61	48·5	23·90	6,744	37·0	35·2
(10)	1 25 30 ,,	23·21	47·0	......	7,180	34·5	33·2
	1 26 0 ,,	22·77	46·0	......	7,694	......	......
	1 27 30 ,,	22·70	43·0	22·75	7,764		
(11)	....	......	......	......	......	......	......
	1 29 0 ,,	......	......	20·85	10,020	32·0	25·8
	1 29 30 ,,	20·63	41·0	20·60	10,342		
(12)	1 30 0 ,,	20·12	40·0	......	11,055	31·5	24·2
	1 32 0 ,,	19·13	40·0	19·15	12,259	......	......
(13)	1 32 30 ,,	......	......	......	(12,600)	23·0	31·0
(14)	1 33 0 ,,	......	......	......	......	......	......
(15)	1 34 0 ,,	......	......	18·35	13,340	......	......
	1 34 10 ,,	......	......	17·95	14,030	......	......
(16)	1 35 0 ,,	......	......	......	(14,600)	21·0	30·0
	1 35 30 ,,	17·24	38·0	17·30	14,986	......	......
(17)	1 37 0 ,,						
(18)	1 38 0 ,,						
(19)	1 39 0 ,,						
	1 40 0 ,,	16·25	30·0	16·25	16,504	17·2	13·0
(20)	1 42 0 ,,	15·86	24·0	15·85	17,057	12·0	6·0
(21)	1 43 0 ,,	15·81	24·0	15·80	17,140	12·1	5·1
(22)	1 47 0 ,,	15·46	......	15·46	17,749	12·0	5·0
(23)	1 48 0 ,,	15·81	......	14·80	18,886	12·0	4·5
	1.	2.	3.	4.	5.		7.

(1) Atmosphere misty and thick; wind N.E.; many clouds; now and then gleams of sunshine.

(2) Rope broke before we were ready; the spectroscope swung round; I was jerked among the instruments; Daniell's and Regnault's Hygrometers were both broken.

(3) Rising too quickly.

(4) Misty.

(5) The line G in the spectrum is very clear; can see H and far beyond. Spectroscope directed to sky, near the sun.

(6) The line B clear; very many lines in sky spectrum.

(7) Crystal Palace and grounds very well seen; mist resting on the earth; cumuli on level with the balloon.

(8) Misty.

(9) The coloration of photographic paper was 2 in 2 or 3 minutes.

(10) Thick mist; almost a fog.

Balloon Ascent, from the Crystal Palace, April 18, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
5·8	50·2							
6·0	48·3	59·2						
6·3	49·1	60·8						
7·3	47·8	61·5						
5·2	48·4							
6·1	45·5							
5·5	45·4							
6·2	43·1							
6·0	42·2							
6·2	36·4							
6·2	34·1	47·0						
6·1	27·5							
3·5	33·6							
1·8	32·7							
1·3	31·1							
......	......	32·8						
......	......	32·2						
6·2	12·1							
7·3	5·9	31·5						
......	......	23·2						
......	......	23·0						
......	......	23·2						
......	......	21·0						
......	......	20·0						
4·2	−19·0	17·0						
6·0	−20·6							
7·0	−49·3							
7·0	−49·5							
7·5	−53·8							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(11) Beyond H and to A in sky spectrum, under and near the sun, lines beautifully defined; great change of focus to see A and H. Sky spectrum at some distance from the sun, less than G; can see B and several lines beyond.

(12) Above the clouds; sea of clouds below; Crystal Palace seen clearly; wind N.

(13) Ozone 3 by powder; 0 by paper.

(14) Balloon full; no sky spectrum; dark. (15) Blue sky above. (16) Gas out.

(17) Spectrum far beyond B, up to A when near sun. (18) Gas clear.

(19) Sky spectrum short at a little distance from sun.

(20) A stream of cold to sense. (21) Minimum thermometer 11°·2.

(22) Lurch in balloon; spectroscope swung round, and from some cause the solar radiation thermometer fell over the side of the car; I looked down, but could not see it.

(23) General tinge over countenance; heart slightly affected; largest field appeared three inches square; lowered grapnel. No spectrum; no lines; looking at sky, which was quite bright from $1^h\ 47^m$ to $1^h\ 49^m$, with the exception of a few seconds before and after $1^h\ 48^m$.

TABLE I.—Meteorological Observations made in the Tenth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	1 49 0 p.m.	14·81	20·0	14·80	18,886	12·0	4·9
	1 50 0 ,,	......	......	......	(19,140)	12·1	6·0
	1 52 0 ,,	14·37	10·5	14·35	19,644	......	......
(1)	1 52 50 ,,	......	......	14·15	20,163	11·5	
(2)	1 53 0 ,,						
(3)	1 54 0 ,,	14·15	30·0	......	24,163	12·1	6·0
	1 55 0 ,,	14·05	......	......	20,338		
(4)	1 56 0 ,,	14·05	30·0	14·15	20,338		
(5)	2 0 0 ,,	13·75	......	......	20,943	14·0	6·0
	2 2 0 ,,	14·05	......	14·05	20,428		
(6)	2 9 0 ,,	......	......	13·65	21,120	......	......
	....	......	......	......	......	15·0	3·0
(7)	2 11 0 ,,	......	......	......	......	......	......
(8)	2 12 0 ,,	13·35	......	13·35	21,646	......	......
	2 13 0 ,,	......	......	13·30	21,760		
(9)	2 14 0 ,,	......	......	13·30	21,760	......	......
	2 15 0 ,,	13·25	......	13·25	21,869	......	......
(10)	2 15 30 ,,	13·20	......	......	22,041	16·0	6·2
	2 22 30 ,,	......	......	12·75	22,954	12·5	0·0
	2 27 0 ,,	......	......	12·60	23,258	......	......
	2 28 0 ,,	......	......	......	......	......	......
	2 28 30 ,,	......	......	12·50	23,460	......	......
	2 29 0 ,,	12·50	......	12·50	23,460		
	2 29 30 ,,	......	......	12·48	23,500		
	2 30 0 ,,	......	......	12·50	23,460		
	2 30 30 ,,	13·35	......	12·35	23,753	12·5	0·5
	2 31 0 ,,	12·45	......	12·55	23,539	......	......
(11)	2 31 30 ,,						
	2 33 0 ,,	12·65	......	......	23,109	......	......
	2 33 10 ,,	......	......	12·75	22,907	12·5	1·0
(12)	2 33 30 ,,	......	......	13·35	21,765		
	2 33 45 ,,	......	......	13·55	21,381		
(13)	2 34 0 ,,	13·65	......	13·65	21,189	13·1	3·0
(14)	....	......	......	......	......	......	......
(15)	2 37 30 ,,	16·64	......	16·24	15,998	15·5	7·0
	2 38 0 ,,	......	......	......	......	......	......
	2 38 30 ,,	17·24	......	......	14,967		
	2 39 0 ,,	......	......	......	(14,670)	16·5	8·8
	2 40 0 ,,	17·64	......	......	14,341		
	2 40 30 ,,	18·14	......	17·95	13,590	16·5	10·0
	2 41 30 ,,	......	......	......	......	17·0	14·5
	2 42 0 ,,	19·94	......	......	11,100	18·0	15·5
	1.	2.	3.	4.	5.	6.	7.

(1) Face bluish white. (2) Examined slit of spectroscope, all seems right; dark field.
(3) Gas clear. (4) Still a dark field; far from sun.
(5) Mr. Coxwell's pulse 113, Mr. Ingelow's 130, mine 90 per minute.
,, 98, ,, 130, ,, 95 ,,
Mr. Glaisher's pulse very weak, Mr. Ingelow's full and strong.
(6) Opened bottles; filled four. (7) No sky spectrum; no lines.
(8) No sky spectrum; no lines. (9) Air very dry to sense.
(10) Sky spectrum B to G close to sun. From this time to $2^h\ 30^m$ I was chiefly engaged with the spectroscope; there was no spectrum at all on looking with the slit directed to the sky far from the sun; on approaching the sun the yellow first appeared, and when very near the sun the spectrum was perfect, increasing in length the nearer we approached

Balloon Ascent, from the Crystal Palace, April 18, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
7·1	− 50·3							
6·1	− 41·4	11·6						
......	......	10·5						
6·1	− 32·6	10·5						
8·0	− 56·0	12·0						
......	......	14·2						
12·0	− 100·0							
......	......	14·5						
......	......	13·0						
......	......	16·5						
......	......	13·2						
9·8	− 69·3							
12·5	− 97·2	12·0						
......	......	12·3						
......	......	12·0						
......	......	12·0						
12·0	− 92·8							
......	......	12·2						
......	......	12·1						
11·5	− 88·4	12·6						
10·1	− 75·4							
......	......	14·5						
8·5	− 55·6	16·0						
......	......	17·0						
7·7	− 50·1	17·0						
6·5	− 39·7	16·5						
2·5	− 4·5	17·1						
2·5	− 3·2	18·0						
8.	9.	10.	11.	12.	13.	14.	15.	16.

the sun; and when a beam of light came from the sun itself, the whole spectrum was visible, the nebulous line H and a good way beyond at the violet end, and A at the red end, with innumerable lines between, particularly at the violet end, all sharp and well-defined; on the balloon revolving the spectrum was gradually lost, till none appeared at the sky opposite the sun. I scarcely moved my eye from the telescope during three revolutions: at the first I examined the violet end; next the red end; and then the whole spectrum.

(11) Looked at sun with red, blue, and yellow glass for anything like prominences; edge without appendages. (12) No change on paper in one minute.

(13) Mr. Coxwell uneasy; opened the valve freely, and we descended rapidly.

(14) No spectrum; could not get the sun.

(15) The readings of the two barometers are discordant I cannot say which is correct.

TABLE I.—Meteorological Observations made in the Tenth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	2 43 0 p.m.	20·04	......	......	11,003	20·0	18·1
	2 43 30 „	20·24	......	......	10,785	24·0	19·0
	2 44 0 „	20·94	......	......	9,609	26·0	20·0
(1)	2 48 0 „	......	......	......	ground	(57·0)	

Meteorological Observations made in the Eleventh

(2)	1 2 0 p.m.	29·70	66·0	29·80	ground	......	......
(3)	1 3 0 „	......	......	......	......	66·0	57·0
	1 4 0 „	29·15	66·0	......	884	65·0	56·0
	1 4 30 „	28·57	66·0	......	1,445	62·0	54·0
	1 6 0 „	......	......	......	......	61·8	53·5
(4)	1 6 15 „	28·36	65·0	28·45	1,660	61·5	53·1
	1 6 30 „	27·86	64·0	......	2,150	59·5	51·5
	1 7 0 „	27·36	64·0	27·55	2,651	57·2	51·2
(5)	1 7 20 „	......	......	......	(3,029)	55·0	49·8
	1 8 0 „	......	......	......	(3,785)	51·0	......
	1 8 10 „	......	......	27·45	(3,974)	50·5	......
	1 8 50 „	25·27	63·5	......	4,729	48·5	......
(6)	1 9 0 „	24·87	......	......	5,264	47·0	40·0
	1 10 0 „	24·58	60·0	......	5,578	......	......
(7)	1 11 0 „	23·79	58·0	......	6,477		
	1 13 0 „	......	......	......	(7,300)	41·2	31·0
	1 13 30 „	22·80	52·0	......	7,510	39·0	29·2
	1 14 0 „	......	......	......	(7,940)	37·2	26·1
	1 15 0 „	21·82	45·0	21·85	8,796	......	......
	1 15 20 „	......	......	......	(8,827)	36·0	26·1
(8)	1 16 0 „	......	......	21·65	8,888		
	1 16 30 „	......	......	20·75	9,298	31·2	32·0
(9)	1 17 0 „	......	......	20·65	9,800	......	......
(10)	1 17 15 „	......	......	20·20	10,800		
	1 17 30 „	20·22	43·5	......	10,804		
(11)	1 17 45 „	19·93	42·0	......	11,204	30·0	31·0
(12)	1 18 0 „	......	......	19·75	11,478		
	1.	2.	3.	4.	5.	6.	7.

(1) Suddenly the South Coast appeared under us, and Mr. Coxwell called out, "Put up the instruments! help me! we shall be in the sea, we cannot go over!" I began to put the instruments up instantly. He called for immediate assistance; we pulled open the valve as wide as possible, and at 2^h 48^m came to the ground with a violent crash; we were of course all thrown down; my head was struck behind, my ankle sprained, and I received a few other trifling bruises. Mr. Coxwell and Mr. Ingelow escaped unhurt; but nearly all the instruments were broken, with the exception of two large bottles of air for Prof. Tyndall; the two other bottles were broken, and unfortunately three very sensitive thermometers which had been kindly furnished me for these experiments by M. A. D'Abbadie. The descent took place about half a mile from the Newhaven Station. It was fully seven or eight minutes before any one came to our assistance. When descending we observed two rents in the balloon, owing to the valve-line having torn it. Mr. Coxwell tenaciously held on to the valve-line, and thus crippled the balloon, which never rose. We returned to London by the train leaving Newhaven at 7^h 30^m. The blue of the sea had been mistaken for mist. Temperature on the ground 57°.

Balloon Ascent, from the Crystal Palace, April 18, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
1·9	+ 4·6	20·5						
5·0	−10·6	24·5						
6·0	−10·4	26·2						

Balloon Ascent, from Wolverton, June 26, 1863.

......	......	66·0						
9·0	49·8	66·0						
9·0	48·7							
8·0	47·2	62·0						
8·3	46·4	61·5						
8·4	45·9	61·0	......	......	......	......	......	48·0
8·0	44·4							
6·0	45·7	......	......	......	......	......	47·0	
5·2	44·9	54·5						
......	......	50·5						
......	......	50·0						
......	......	49·0						
7·0	32·2	46·0						
......	......	43·0						
10·2	18·1							
9·8	16·3	38·5						
11·1	10·4	37·0						
......	......	......	......	......	......	......	11·0	
9·9	11·3	36·0						
......	......	......	......	......	......	......	......	8·0
......	......	31·5						
8.	9.	10.	11.	12.	13.	14.	15.	16.

(2) Wind W.S.W.; strong. Balloon lurched considerably; fifty men were not sufficient to keep it down; the instruments were with difficulty mounted on the board in the car.

(3) The sky was cloudy, after a fine morning.

(4) The lower atmosphere very dark.

(5) Painfully cold. (6) Terribly cold.

(7) Dreadfully cold; put on coat with difficulty; wrapped up my neck; put on extra cap; gave Mr. Coxwell a wrapper.

(8) Faint sun; at this time the sighing, or rather moaning of the wind was heard as preceding a storm; it is the first instance that either Mr. Coxwell or myself had heard such a sound.

(9) Fine rain falling.

(10) Saw sun faintly.

(11) In fog, thin rain; lost sight of sun.

(12) Worked bellows for Regnault's Hygrometer.

TABLE I.—Meteorological Observations made in the Eleventh

References to Notes	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	1 18 20 p.m.	19·83	42·0	......	11,341	31·1	31·0
(2)	1 19 0 ,,	19·23	41·5	19·25	12,177		
(3)	1 19 30 ,,	......	......	19·05	12,459		
(4)	1 20 0 ,,	18·83	41·5	......	12,743	30·5	30·5
(5)	1 20 10 ,,	18·53	41·0	......	13,173	......	......
(6)	1 21 0 ,,	18·13	41·0	18·15	13,764	......	......
(7)	1 21 10 ,,	18·03	41·0	18·00	13,913	31·0	31·0
(8)	1 22 0 ,,						
(9)	1 23 0 ,,	17·63	41·0	......	14,530	32·0	29·0
(10)	1 24 0 ,,	17·13	42·0	......	15,295		
(11)	1 25 0 ,,	16·93	41·0	......	15,598	30·0	29·0
(12)	1 25 20 ,,	16·83	41·0	......	15,757	30·0	29·0
	1 26 0 ,,	16·73	40·0	......	15,935	29·0	26·0
(13)	1 27 0 ,,	16·63	41·0	......	16,079	30·0	26·0
	1 28 0 ,,	16·63	40·0	16·65	16,079	32·0	27·6
	1 28 30 ,,	......	......	......	......	......	......
	1 29 0 ,,	16·53	40·0	16·55	16,274	32·0	27·0
	1 29 20 ,,	......	......	......	(16,274)	33·0	28·5
(14)	1 29 30 ,,	16·53	40·0	16·55	16,274		
	1 29 45 ,,	......	......	16·40	16,486	35·0	30·0
(15)	1 30 0 ,,	......	......	......	(16,548)	35·0	29·8
	1 31 0 ,,	16·23	......	16·25	16,796		
(16)	1 31 30 ,,	......	......	16·15	16,870	34·5	29·2
(17)	1 32 0 ,,	16·03	41·5	16·05	17,144		
(18)	1 32 10 ,,	16·03	......	......	17,144		
(19)	1 32 30 ,,	16·03	41·5	16·05	17,144	......	......
(20)	1 33 0 ,,	15·93	......	......	17,242		
	1 33 30 ,,	15·88	41·5	......	17,339	......	......
(21)	1 34 0 ,,	15·83	41·5	15·90	17,479	34·2	28·1
(22)	1 34 0 ,,	......	......	......	......	......	......
	1 35 0 ,,	15·83	41·5	15·85	17,479		
	1 35 30 ,,	15·49	41·0	15·45	18,053	33·0	23·1
(23)	1 36 0 ,,	15·33	......	15·35	18,291		
	1 36 20 ,,	15·23	41·0	15·25	18,435	29·2	21·2
	1 36 30 ,,	15·23	42·0	15·15	18,435	......	......
	1 36 45 ,,	15·13	42·0	15·15	18,555	26·2	21·0
(24)	1 37 0 ,,	......	......	15·15	18,560	25·0	19·0
	1 38 0 ,,	......	......	......	(18,790)	25·0	18·5
(25)	1 39 0 ,,	14·83	42·0	......	19,018	21·8	
(26)	1 39 10 ,,						
(27)	1 40 0 ,,						
(28)	1 40 0 ,,	14·73	40·5	15·75	19,178	20·6	16·2
(29)	1 40 40 ,,	......	......	......	(19,420)	20·5	16·0
(30)	1 41 0 ,,	14·53	41·0	14·55	19,544	......	......
	1.	2.	3.	4.	5.	6.	7.

(1) In fog; just see the earth; misty. (2) See the sun faintly.
(3) Lowered grapnel very gradually. (4) Sun just visible; thin wet fog.
(5) Mr. Coxwell requested me to open the valve whilst he lowered the grapnel.
(6) See the sun faintly through wet fog. (7) Valve opened.
(8) Mr. Coxwell complained of pain in his hands, which were dark blue.
(9) Assisted in lowering the grapnel. (10) In fog, not wet.
(11) In dry fog. (12) Ice on Wet-bulb. (13) In fog.
(14) Faint gleams of light. (15) New Barometer nearly 16·60 inches.
(16) Train heard. (17) A period of calm, and warm to senses.

Balloon Ascent, from Wolverton, June 26, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometer.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	33·0						
......	......	32·0						
......	......	......	......	......	......	......	......	20·0
......	......	33·0						
......	......	......	......	......	......	......	20·0	
......	......	......	......	......	......	......	20·0	
3·0	15·2	......	......	......	......	......	......	17·2
4·0	13·4	......	......	......	......	......	17·0	
4·4	17·1	34·5	33·0	26·9	6·1	14·9		
......	......	......	......	......	......	......	22·0	20·5
5·0	(15·4)							
4·5	16·8	......	......	......	......	......	......	21·0
5·0	22·0	36·2	......	......	......	......	......	24·2
5·2	21·5	35·6	......	......	......	......	......	23·5
5·3	17·4	......	35·0	27·0	8·0	14·2		
......	......	35·2						
......	......	34·7						
6·1	17·4	......	34·2	27·6	6·6	15·7		
......	......	......	......	......	......	......	......	19·2
9·9	3·3	33·4	......	......	......	......	9·0	
8·0	− 7·8	30·5						
......	......	......	......	......	......	......	......	−10·1
5·2	− 5·0	26·5	......	......	......	......	......	− 9·2
6·0	−14·1	......	......	......	......	......	......	− 5·0
6·5	−17·4	24·9	......	......	......	......	− 4·0	− 4·2
4·4	−14·6	20·5	......	......	......	......	......	− 8·0
4·5	−15·5	......	20·0	16·0	4·0			
......	......	......	......	......	......	......	......	−11·0
8.	9.	10.	11.	12.	13.	14.	15.	16.

(18) Still in cloud. (19) Clouds above us still.
(20) Cloudy, and gas rushing out of the balloon in volumes. (21) Still in cloud.
(22) A sudden cloud. (23) In a wetting fog. (24) Cold, dry, thin fog.
(25) Getting clearer; faint blue sky.
(26) Just above cloud; cirri above; cloud on same level as the car all round.
(27) Clouds very high.
(28) Sun faintly shining, but cut off by the balloon.
(29) do do
(30) do do

TABLE I.—Meteorological Observations made in the Eleventh

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	1 41 10 p.m.	14·53	41·0	14·55	19,544	20·0	16·0
(2)	1 41 30 „						
(3)	1 41 45 „	14·33	41·0	......	19,909	20·5	16·0
	1 42 0 „	14·23	41·0	......	20,167	21·1	16·0
(4)	1 42 30 „	14·24	41·0	14·25	20,167	21·1	16·0
(5)	1 42 45 „						
(6)	1 43 0 „	......	......	13·95	20,648	21·0	16·0
(7)	1 43 30 „	......	......	......	......	19·1	16·1
(8)	1 44 0 „	13·94	40·0	13·95	20,648	20·0	16·0
(9)	1 45 0 „	13·84	......	13·85	20,854		
(10)	1 46 0 „	13·64	40·0	13·65	21,266	22·0	16·1
(11)	1 47 0 „	13·59	......	......	21,357	22·0	16·0
(12)	1 48 0 „	13·34	......	13·35	21,978	......	......
	1 49 0 „	13·24	......	......	22,053		
(13)	1 50 0 „	13·24	......	......	22,053	22·0	16·0
	1 51 0 „	......	......	13·20	22,073	21·8	16·0
	1 53 0 „	13·14	......	......	22,105		
	1 53 30 „	13·14	32·0	13·40	22,105	19·2	16·1
	1 53 35 „	......	......	......	......	......	......
	1 53 40 „	......	......	......	......	......	......
	1 53 45 „	......	......	......	......	......	......
(14)	1 54 0 „	12·89	......	......	22,664	......	......
(15)	1 54 30 „	......	......	......	(23,023)	18·5	16·0
(16)	1 54 40 „	12·66	......	......	23,143	18·0	......
(17)	1 54 50 „	......	......	......	(23,200)	17·0	16·2
	1 55 0 „	13·04	......	13·05	22,965	......	......
	1 56 0 „	......	......	......	......	......	......
(18)	1 57 0 „						
(19)	1 58 0 „	13·14	......	12·95	22,168	19·1	......
	1 58 30 „	13·54	......	......	21,457	......	......
	1 59 0 „	13·65	33·0	13·65	21,302		
	2 0 0 „	13·85	......	13·75	20,934	26·1	21·8
	2 1 0 „	14·25	33·0	......	20,167		
(20)	2 2 0 „	14·25	33·0	......	20,167	26·1	22·0
(21)	2 2 30 „	14·25	33·0	......	20,167	......	......
(22)	2 2 45 „	14·25	34·0	14·27	20,167		
	2 3 0 „	14·44	35·0	14·45	19,901	26·0	24·0
(23)	2 4 30 „	14·64	35·0	14·65	19,367	23·0	......
(24)	2 4 45 „	......	......	......	......	23·2	23·1
	2 5 0 „	14·44	35·0	......	19,901	23·0	22·0
	1.	2.	3.	4.	5.	6.	7.

(1) Sun just visible, but cut off by the balloon.
(2) In fog again; sun invisible.
(3) Three layers of clouds we have passed; clouds still higher.
(4) Sky very pale blue between clouds.
(5) Spectrum at blue sky same as on ground.
(6) Rain-cloud to the right; two nimbus clouds near us and on the same level as ourselves.
(7) Saw the sun; the reading of the actinometer increased 8·6 div. in sun; then 3·1 div. in faint sun; then fell 2·7 div. in shade; then increased 0·8 div. in sun; and then 1·5 div. in sun in one minute.
(8) In fog.
(9) New Barometer 14·20 inches.
(10) In fog.
(11) Sun invisible.
(12) Train heard.

Balloon Ascent, from Wolverton, June 26, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
4·0	−12·5	20·0	......	......	......	......	......	− 9·5
4·5	15·5							
5·1	−19·0	24·1	......	......	......	......	......	− 9·0
5·1	−19·0	21·5						
5·0	−18·9	21·0						
3·0	− 5·9	......	19·5	15·8	3·7	......	......	−13·0
4·0	−12·5	......	......	......	......	......	......	−13·0
5·9	−22·8	22·0	......	......	......	......	......	−13·0
6·0	−23·6	22·0						
......	......	23·0						
6·0	−23·6							
5·8	−22·2							
3·1	− 6·5							
......	......	......	......	......	......	......	......	− 3·1
......	......	......	......	......	......	......	− 3·5	
......	......	......	......	......	......	......	− 3·5	
......	......	18·5						
2·5	− 2·5	......	......	......	......	......	......	+ 3·0
......	......	17·0	18·0	16·1	1·9	1·8	+ 1·5	
0·8	+10·2	......	18·0					
......	......	18·0	19·0	18·0	1·0	10·7	......	+ 2·5
......	......	......	......	......	......	......	+ 2·2	
......	......	19·1	......	......	......	......	......	+ 2·0
......	......	23·0	......	......	......	......	......	2·0
4·3	0·0	26·1						
4·1	+ 1·2	26·1						
......	......	26·1						
2·0	13·8	26·0						
......	......	23·1						
0·1	22·3	......	......	......	......	......	......	15·0
1·0	15·8	22·0	......	......	......	......	18·0	
8.	9.	10.	11.	12.	13.	14.	15.	16.

(13) We looked round at the very faint blue sky, covered with cirri, and estimated the height of the cloud to be many miles; atmosphere thick and misty.
(14) Cirri alone above; sky faint blue; spectrum with small instrument same as below.
(15) Could not use large spectroscope.
(16) We are above cloud, but not free from mist.
(17) No fine views or forms, all confused and dirty-looking; the sky is the same as seen from below; we have very little sand; cannot go higher.
(18) Faint blue sky above; clouds. (19) Ozone 2.
(20) Sun very faint.
(21) Spectrum B to F; actinometer rose 5 divisions in one minute.
(22) In fog; sun invisible.
(23) In fog; very chilly. (24) In fog.

TABLE I.—Meteorological Observations made in the Eleventh

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	....	......	......	......	......	......	......
(2)	2 6 0 p.m.						
	2 6 10 ,,	......	......	......	......	23·0	21·5
(3)	....	......	......	......	......	......	......
	2 6 20 ,,	14·34	35·0	......	20,025	......	......
	2 6 45 ,,	......	......	......	......	25·0	23·0
	2 7 0 ,,	14·04	35·0	......	20,630	28·9	23·0
(4)	2 7 30 ,,	14·34	34·0	14·35	20,025	28·1	23·7
	2 8 0 ,,	14·64	34·0	14·65	19,367	27·5	23·6
(5)	2 8 30 ,,	14·84	34·0	14·85	19,089	......	......
	2 9 0 ,,	15·04	34·0	......	18,746	28·0	24·0
	2 9 30 ,,	......	......	......	......	29·2	23·1
	2 10 0 ,,	15·34	34·0	15·35	18,235		
	2 10 15 ,,	......	......	......	......	29·0	23·5
(6)	2 10 20 ,,	......	......	......	......	......	......
	2 10 45 ,,	15·54	35·0	15·55	17,888	29·5	24·5
	2 11 0 ,,	16·04	35·0	......	17,422	29·5	24·5
(7)	2 11 15 ,,	16·24	......	......	16,776	......	......
	2 11 30 ,,	......	......	16·35	16,594		
	2 11 45 ,,	......	......	......	......	31·5	26·0
	2 12 0 ,,	16·44	36·0	......	16,412	32·0	26·0
	2 12 30 ,,	......	......	......	......	32·5	26·2
	2 13 0 ,,	16·84	36·0	......	15,762	32·0	27·0
	2 13 15 ,,	......	......	16·95	15,602		
	2 13 30 ,,	16·99	36·0	......	15,521		
	....	......	......	......	......	......	......
(8)	2 14 0 ,,	17·39	......	17·40	14,892	......	......
(9)	2 14 15 ,,	......	......	......	......	33·0	27·0
	2 14 30 ,,	17·64	36·0	......	14,501		
(10)	2 14 45 ,,	17·84	......	......	14,197	......	......
(11)	2 14 50 ,,	18·04	36·0	......	13,896	33·0	29·2
(12)	2 15 0 ,,	......	......	......	......	33·0	29·2
(13)	2 15 5 ,,						
	2 15 10 ,,	18·74	......	......	12,865	......	......
(14)	2 15 30 ,,	19·04	36·0	......	12,433	......	......
(15)	2 15 45 ,,	......	......	......	......	33·0	29·5
(16)	2 16 0 ,,	19·77	36·0	......	11,412		
	2 16 30 ,,	......	......	20·05	......	33·0	27·5
(17)	2 17 0 ,,	20·44	......	20·45	10,508	33·0	27·0
(18)	2 18 0 ,,	20·77	......	......	10,011	33·0	26·5
(19)	2 19 0 ,,	20·77	......	......	10,011	33·5	26·0
	2 19 30 ,,	20·89	......	......	9,917		
	2 19 45 ,,	21·29	......	......	9,402		
(20)	2 20 20 ,,	21·49	36·0	21·50	9,148	33·5	26·0
(21)	2 20 30 ,,	22·33	37·0	22·35	8,107	34·5	27·2
	1.	2.	3.	4.	5.	6.	7.

(1) In fog. (2) Faint gleams of light.
(3) Faint gleams of light; fog above and below, none near us.
(4) Drops of water falling from the balloon.
(5) In fog; no dew at 15°.
(6) In fog. (7) In fog. (8) In thin fog.
(9) Thin rain pattering on the balloon, and moving against us.
(10) Snow falling fast. (11) Snow-storm; dark everywhere.
(12) Spicula, cross spicula.

Balloon Ascent, from Wolverton, June 26, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
......	......	......	......	......	......	......	......	16·5
1·5	12·7	23·0						
......	......	......	23·0	21·0	2·0			
......	......	23·0						
2·0	12·0	25·8						
5·9	1·5							
4·4	5·6							
3·9	5·4	......	27·0	23·1	3·9			
......	......	......	......	......	......	......	......	15·2
4·0	7·6							
6·1	1·1							
5·5	4·6							
......	......	......	29·0	23·0	6·0	+1·4		
5·0	7·5	30·0						
5·0	7·5							
......	......	31·0						
5·5	12·2	31·5						
6·0	12·1							
6·3	12·6	......	......	......	......	......	......	15·0
5·0	15·4	32·0						
......	......	......	31·5	27·0	4·5	15·8		
......	......	33·0						
6·0	14·9	33·5						
......	......	33·0						
3·8	21·6	33·0						
3·8	21·6	33·0						
......	......	33·0						
......	......	33·0						
3·5	22·5	33·0						
5·5	16·4							
6·0	14·9							
6·5	13·4							
7·5	11·8							
7·5	11·8							
7·3	14·9							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(13) Many six-sided figures, small but distinct, all icy particles.
(14) Dense snow, no flakes; sand out.
(15) Snow appeared to rise.
(16) Sand out, golden appearance, mixing with snow.
(17) No snow.
(18) Lower atmosphere very murky.
(19) Lower atmosphere has a yellowish-brown tinge, remarkably dull.
(20) Two canals in sight, straight for many miles.
(21) Lower atmosphere very murky; Mr. Coxwell had never seen it in such a state before, when far from a town.

TABLE I.—Meteorological Observations made in the Eleventh

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	2 21 0 p.m.	......	......	24·25	(5,870)	38·0	
(1)	2 22 0 ”	24·72	......	24·75	5,319	39·2	33·0
(2)	2 23 0 ”	......	......	......	......	42·0	35·1
(3)	2 24 0 ”	......	......	......	......	43·0	37·0
	2 25 0 ”	25·81	......	......	4,138		
	2 25 30 ”	26·60	......	......	3,394	46·2	43·1
	2 26 0 ”	26·70	......	......	3,293	47·0	43·0
	2 27 0 ”	28·18	......	......	1,810		
	2 27 30 ”	28·76	......	......	1,259		
	2 28 0 ”	29·26	......	......	779		
(4)	2 28 + ”	30·10	......	29·85	ground	66·5	60·0

Meteorological Observations made in the Twelfth

References to Notes.	Time.	Reading	Att. Therm.	Aneroid	Height	Dry.	Wet.
	4 44 0 p.m.	......	......	30·12	on the ground.	75·2	62·1
	4 45 0 ”	......	......	30·12		74·9	62·0
	4 46 0 ”	......	......	30·12		74·5	62·0
(5)	4 47 0 ”	......	......	30·12		74·2	61·5
	4 48 0 ”	......	......	......	......	......	......
	4 51 0 ”	......	......	......	......	74·1	61·0
	4 53 0 ”	......	......	30·11	on the ground.	74·0	61·6
	4 54 0 ”	......	......	......	......	73·5	60·5
(6)	4 55 0 ”						
	4 55 + ”	......	......	29·80	523		
	4 56 30 ”	......	......	29·55	748	......	......
	4 57 0 ”	......	......	29·35	928	70·2	57·0
	4 58 0 ”	......	......	29·15	1,150	......	......
	4 58 20 ”	......	......	28·85	1,494	65·0	57·0
	4 58 50 ”	......	......	28·55	1,788	......	......
	4 59 0 ”	......	......	28·30	2,036	62·8	51·5
	4 59 10 ”	......	......	28·00	2,283	62·0	52·0
(7)	4 59 30 ”	......	......	27·65	2,633		
	5 1 30 ”	......	......	26·70	3,580	59·5	51·0
	5 2 0 ”	......	......	26·55	3,730	......	......
	5 2 30 ”	......	......	26·50	3,780	......	......
	5 4 0 ”	......	......	26·35	3,930	59·0	52·0
	5 5 0 ”	......	......	26·30	3,980	61·5	54·2
	5 5 30 ”	......	......	26·25	4,030	60·5	53·2
	5 5 45 ”	......	......	26·11	4,170	60·2	53·5
(8)	5 6 0 ”	......	......	26·05	4,233	59·2	54·1
	5 7 0 ”	......	......	26·00	4,366	59·0	54·1
	5 7 30 ”	......	......	25·78	4,610	60·0	54·8
(9)	5 9 0 ”						
	5 13 0 ”	......	......	26·40	3,860	64·0	56·0
	5 14 0 ”	......	......	26·40	3,860	63·5	55·0
	1.	2.	3.	4.	5.	6.	7.

(1) Put up instruments.
(2) No sand; threw away leaden weights, &c.
(3) Cannot see any distance on land.
(4) Wind very strong; the descent was very rough and difficult. We descended in a corn-field adjoining the farm of H. Jones, Esq., on the borders of the counties of Cambridge and Norfolk.

Balloon Ascent, from Wolverton, June 26, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
6·2	24·8							
6·9	26·6							
6·0	29·8	43·0	43·0	37·0	6·0	29·8		
3·1	39·6							
4·0	38·5							
6·5	54·7							

Balloon Ascent, from the Crystal Palace, July 11, 1863.

13·1	52·7	74·2	......	......	......	......	55·0	
12·9	52·8	......	......	......	......	......	53·5	
12·5	52·9	73·8						
12·7	52·2	......	......	......	......	......	55·0	
......	......	73·3						
13·1	51·4	73·2	......	......	......	......	54·0	
12·4	52·6	73·5						
13·0	50·9	73·5						
......	......	69·2						
13·2	46·9							
......	......	66·5						
8·0	50·4							
......	......	64·0						
11·3	41·9	62·5						
10·0	43·4	61·5						
8·5	43·5	59·2						
......	......	57·8						
......	......	57·5						
7·0	45·8	......	......	......	......	......	46·0	
7·3	47·9	61·5						
7·3	46·8	60·5	......	......	......	......	46·5	
6·7	47·6	60·5						
5·1	49·5							
4·9	49·7	......	......	......	......	......	51·5	
5·2	50·3	......	......	......	......	......	48·5	
8·0	49·4	65·0						
8·5	47·9	64·0	......	......	......	......	49·0	
8.	9.	10.	11.	12.	13.	14.	15.	16.

(5) Wind East. (6) Balloon left the earth.
(7) Balloon entered north current; changed direction. (8) Near Croydon.
(9) Beautiful view everywhere.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 14 30 p.m.	......	......	26·38	3,832		
(2)	5 15 0 „	......	......	......	......	61·5	54·2
	5 16 0 „	......	......	26·10	4,171	62·0	55·0
	5 17 30 „	......	......	26·10	4,171		
(3)	5 19 0 „	......	......	......	......	63·0	56·0
	5 21 0 „	......	......	26·52	3,771	64·1	56·2
	5 22 0 „	......	......	26·65	3,660	65·0	56·5
	5 23 0 „	......	......	26·70	3,610	65·0	57·0
	5 24 0 „	......	......	26·78	3,524	65·0	57·0
	5 24 0 „	......	......	27·10	3,219	66·0	57·5
	5 24 30 „	......	......	......	......	65·5	57·8
	5 26 0 „	......	......	......	......	65·5	57·6
	5 27 0 „	......	......	......	......	......	......
(4)	5 27 30 „						
(5)	5 28 0 „	......	......	26·70	3,581	65·5	57·0
	5 29 0 „	......	......	26·65	3,684	64·2	56·5
(6)	5 29 30 „	......	......	......	......	63·8	56·5
	5 29 45 „	......	......	26·75	3,580	64·2	56·5
(7)	5 30 0 „	......	......	27·05	3,195	65·0	57·0
(8)	5 32 0 „	......	......	27·50	2,765	65·0	57·1
(9)	5 33 0 „	......	......	27·70	2,575	65·2	57·0
(10)	5 34 0 „	......	......	27·85	2,470	65·2	57·0
(11)	5 35 0 „	......	......	28·00	2,287	65·0	56·8
(12)	5 36 0 „	......	......	27·95	2,332		
(13)	5 37 0 „	......	......	27·80	2,469	65·2	56·8
	5 38 0 „	......	......	27·90	2,377	65·0	56·8
(14)	5 39 0 „	......	......	27·85	2,424	......	......
(15)	5 40 0 „	......	......	27·85	2,424	66·0	56·0
(16)	5 41 0 „	......	......	27·80	2,469	66·0	55·5
	5 42 0 „	......	......	27·80	2,470	66·0	55·5
(17)	5 43 0 „	......	......	27·80	2,470		
(18)	5 43 30 „	......	......	27·78	2,488	65·5	56·0
	5 44 0 „	......	......	27·79	2,488	65·3	56·0
(19)	5 45 0 „	......	......	27·78	2,488	65·0	56·1
	5 47 30 „	......	......	27·50	2,762	64·5	57·0
	5 48 0 „	......	......	27·45	2,817	65·0	57·0
(20)	5 49 0 „	......	......	27·45	2,820	65·2	57·3
	5 50 0 „	......	......	27·45	2,820	65·5	57·8
(21)	5 51 0 „	......	......	27·50	2,762	65·5	57·2
	5 52 0 „	......	......	27·55	2,707	65·5	57·8
(22)	5 52 30 „	......	......	27·50	2,762	65·5	57·2
	5 53 0 „	......	......	27·35	2,926	65·0	56·2
	5 53 30 „	......	......	27·20	3,046	65·0	56·2
	5 54 0 „	......	......	27·10	3,157	64·2	56·5
	5 54 30 „	......	......	27·00	3,266	64·2	56·0
(23)	5 55 0 „	......	......	......	......	64·0	56·0
	1.	2.	3.	4.	5.	6.	7.

(1) Thin mist. (2) Atmosphere thick and misty.
(3) Cheering of people assembled at Catherham.
(4) The Times Newspaper folded four times fell over the side of the car.
(5) Sky spectrum B to G. (6) Atmosphere thick and misty.
(7) The Newspaper which fell at $5^h\ 27\frac{1}{2}^m$ is still visible; it looks like a bird.
(8) Sand out. (9) Paper not reached the ground.
(10) Sand out. (11) Paper has reached the ground.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
7·3	47·9	61·5	......	......	......	......	50·2	
7·0	49·0	62·0	......	......	......	......	49·2	
7·0	50·1	63·0						
7·9	49·6	64·1						
8·5	49·5	65·0						
8·0	50·4	65·0						
8·0	50·4	......	......	......	......	......	53·0	
8·5	50·6							
7·7	51·5							
7·9	51·1							
......	......	......	......	......	......	......	51·5	
8·5	50·2	64·5						
7·7	50·1	......	......	......	......	......	50·5	
7·3	50·4							
7·7	50·1	......	......	......	......	......	51·5	
8·0	50·4							
7·9	50·6							
8·2	50·3							
8·2	50·3	......	......	......	......	......	50·8	
8·2	50·0							
8·4	49·9	......	......	......	......	......	50·5	
8·2	50·0							
......	......	65·5						
10·0	47·9	......	......	......	......	......	52·0	
10·5	47·0							
10·5	47·0	......	......	......	......	......	50·5	
9·5	48·3	......	......	......	......	......	50·9	
9·3	48·4							
8·9	48·8	......	......	......	......	......	49·5	
7·5	50·8							
8·0	50·4	......	......	......	......	......	50·0	
7·9	50·9	......	......	......	......	......	50·0	
7·7	51·6	......	......	......	......	......	50·5	
8·3	50·4							
7·7	51·6	......	......	......	......	......	51·0	
8·3	50·4							
8·8	49·0	......	......	......	......	......	50·0	
8·8	49·0	......	......	......	......	......	50·0	
7·7	49·9							
8·2	49·2							
8·0	49·4							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(12) Over Epsom Downs. (13) About five miles from Reigate.
(14) Sand out. (15) Close to Grand Stand on Epsom Downs.
(16) Sand out. (17) Crystal Palace and Shooter's Hill visible.
(18) The two towers of the Crystal Palace not quite in a straight line with us.
(19) Sand out. (20) Near Reigate.
(21) A very fine view; crossing high road. (22) Sun seen faintly.
(23) Faint gleams of sun.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	5 56 0 p.m.	......	......	26·78	3,529	63·5	56·0
	5 57 0 ,,	......	......	26·75	3,562	63·5	56·0
(2)	5 59 0 ,,	......	......	26·75	3,562	63·2	56·0
	6 0 0 ,,	......	......	26·70	3,617	63·2	56·0
	6 1 0 ,,	......	......	......	......	63·2	56·1
	6 2 0 ,,	......	......	26·78	3,529	63·2	56·1
	6 3 0 ,,	......	......	27·05	3,250	63·0	56·1
	6 3 30 ,,	......	......	27·05	3,250	63·0	56·5
(3)	6 4 0 ,,	......	......	27·05	3,250	63·0	56·5
(4)	6 5 0 ,,	......	......	26·78	3,529	62·0	55·1
(5)	6 5 30 ,,	......	......	26·58	3,720	61·0	54·1
(6)	6 7 0 ,,	......	......	26·15	4,133	60·0	52·8
	6 8 0 ,,	......	......	25·80	4,610	58·5	52·5
	6 9 0 ,,	......	......	25·80	4,610	58·2	52·3
	6 12 0 ,,	......	......	25·48	4,905	56·8	53·0
(7)	6 13 0 ,,	......	......	25·30	5,105	56·8	53·0
(8)	6 14 0 ,,	......	......	25·15	5,271	56·8	52·1
	6 15 0 ,,	......	......	25·10	5,327	56·8	52·5
(9)	6 16 0 ,,	......	......	25·05	5,382	57·0	54·0
	6 17 0 ,,	......	......	24·90	5,550	56·8	51·9
	6 17 30 ,,	......	......	......	......	......	......
	6 18 0 ,,	......	......	24·78	5,684	56·2	51·5
	6 19 0 ,,	......	......	24·75	5,718	56·2	51·5
	6 20 0 ,,	......	......	24·70	5,772	56·2	51·2
	6 21 0 ,,	......	......	24·65	5,828	56·1	51·0
(10)	6 22 0 ,,	......	......	24·60	5,884	56·0	50·5
	6 22 30 ,,	......	......	24·45	6,052	55·5	49·5
	6 23 0 ,,	......	......	......	......	......	......
	6 24 0 ,,	......	......	24·10	6,451	53·5	47·2
	6 27 0 ,,	......	......	23·95	6,623	54·8	46·5
	6 28 0 ,,	......	......	23·95	6,623	52·2	46·8
	6 29 0 ,,	......	......	23·98	6,588	52·5	47·0
(11)	6 31 0 ,,	......	......	24·20	6,328	53·0	47·0
	6 32 0 ,,	......	......	24·32	6,186	53·0	47·1
	6 33 0 ,,	......	......	24·32	6,186	53·0	47·0
	6 34 0 ,,	......	......	24·32	6,186	53·0	47·0
	6 35 0 ,,	......	......	24·30	6,210	53·0	47·0
	....	......	......	24·30	6,210		
	6 38 0 ,,	......	......	24·50	5,976	53·0	48·2
	6 40 0 ,,	......	......	24·45	6,031	53·0	47·5
	6 46 0 ,,	......	......	24·40	6,087	52·5	47·0
	6 47 0 ,,	......	......	24·45	6,031	52·2	47·8
	6 47 30 ,,	......	......	......	......	52·3	47·5
	6 48 0 ,,	......	......	24·20	6,309	51·8	47·1
	6 49 0 ,,	......	......	24·15	6,365	51·5	47·2
	6 50 0 ,,	......	......	24·10	6,420	51·1	46·8
	6 51 0 ,,	......	......	24·10	6,420	51·0	46·5
(12)	6 52 0 ,,	......	......	24·07	6,453	51·2	45·5
	6 53 0 ,,	......	......	24·05	6,475	51·1	46·0
	1.	2.	3.	4.	5.	6.	7.

(1) Faint gleams of sun.
(2) Ozone: Moffat 1; Schönbein 0·5; Lowe 3.
(3) Sand out; misty.
(4) Chilly to sense.
(5) Misty.
(6) Ozone: Moffat 1; Schönbein 1; Lowe 3.
(7) Sand out.
(8) Very misty.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
7·5	49·8	......	......	......	......	......	50·0	
7·5	49·8							
7·2	50·0							
7·2	50·0							
7·1	50·2	......	......	......	......	......	50·0	
7·1	50·2							
6·9	50·3	......	......	......	......	......	50·0	
6·5	49·8							
6·5	49·8	......	......	......	......	......	51·0	
6·9	49·2							
6·9	48·1	......	......	......	......	......	50·3	
7·2	46·4							
6·0	47·1							
5·9	47·0	57·7	......	......	......	......	49·0	
3·8	49·5	56·0	......	......	......	......	49·2	
3·8	49·5	......	......	......	......	......	50·0	
4·7	47·8	......	......	......	......	......	49·0	
4·3	48·6	......	......	......	......	......	49·0	
3·0	51·2	......	......	......	......	......	49·5	
4·9	47·6							
......	......	......	......	......	......	......	49·3	
4·7	47·2	......	......	......	......	......	48·0	
4·7	47·2							
5·0	46·6	......	......	......	......	......	47·1	
5·1	46·4	......	......	......	......	......	47·0	
5·5	45·5	......	......	......	......	......	46·5	
6·0	43·1							
......	......	......	......	......	......	......	46·0	
6·3	40·9	......	......	......	......	......	42·5	
8·3	38·6	......	......	......	......	......	42·0	
5·4	41·4							
5·5	41·5							
6·0	41·8	53·0						
5·9	41·2	53·0	......	......	......	......	41·5	
6·0	41·0	53·0						
6·0	41·0	53·0	......	......	......	......	41·5	
6·0	41·0	53·1	......	......	......	......	40·8	
4·8	43·4							
5·5	42·0							
5·5	41·5							
4·4	43·4	......	......	......	......	......	42·0	
4·8	42·5	......	......	......	......	......	41·8	
4·7	43·0	......	......	......	......	......	41·5	
4·3	42·8	51·2						
4·3	42·4	51·0	......	......	......	......	41·5	
4·5	41·9	51·1						
5·7	39·6	......	......	......	......	......	40·4	
5·1	40·7	......	......	......	......	......	40·0	
8.	9.	10.	11.	12.	13.	14.	15.	16.

(9) Over Horsham.
(10) Cirrus and cirrostratus clouds far above.
(11) Very thick; objects below are very indistinct.
(12) The coast at Brighton is distinctly visible.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	6 54 0 p.m.	......	......	......	......	51·1	46·5
	6 54 30 „	......	......	24·00	6,530	51·1	46·0
	6 55 0 „	......	......	23·95	6,588	51·1	46·0
(1)	6 55 30 „	......	......	23·95	6,588	51·1	46·0
	6 56 0 „	......	......	24·00	6,530	51·5	46·0
	6 56 30 „	......	......	24·00	6,530	51·5	46·0
	6 57 0 „	......	......	24·32	6,155	51·4	46·8
	6 58 0 „	......	......	24·50	5,975	54·0	47·8
(2)	6 59 0 „	......	......	24·90	5,523	52·2	47·1
	7 0 0 „	......	......	25·10	5,298	52·5	48·1
	7 1 0 „	......	......	25·05	5,355	53·2	48·3
	7 1 30 „	......	......	25·25	5,150	53·8	49·1
	7 2 0 „	......	......	25·40	4,995	54·2	50·0
	7 2 30 „	......	......	25·55	4,840	54·0	50·0
	7 3 0 „	......	......	25·68	4,706	54·2	50·5
	7 3 30 „	......	......	25·70	4,685	54·2	51·0
(3)	7 3 45 „	......	......	25·85	4,532	55·0	51·1
	7 4 0 „	......	......	26·00	4,380	55·2	51·1
	7 5 15 „	......	......	26·32	4,044		
	7 5 45 „	......	......	26·32	4,044	56·2	51·0
	7 6 0 „	......	......	26·40	3,960	56·8	51·0
	7 6 30 „	......	......	26·50	3,855	57·0	51·0
	7 7 0 „	......	......	26·55	3,802	57·0	50·5
(4)	7 7 30 „	......	......	26·70	3,645	57·2	51·0
	7 8 0 „	......	......	27·05	3,277	58·5	50·5
	7 9 0 „	......	......	27·20	3,120	59·5	50·0
	7 9 30 „	......	......	27·25	3,068	59·5	50·5
(5)	7 9 45 „	......	......	27·40	2,910	59·5	50·5
	7 10 0 „	......	......	27·40	2,910	59·2	50·5
	7 10 15 „	......	......	27·50	2,805	59·2	50·5
	7 10 30 „	......	......	27·62	2,679	59·5	50·0
	7 10 45 „	......	......	27·70	2,595	59·5	50·2
	7 11 30 „	......	......	28·00	2,280	60·1	50·5
	7 12 0 „	......	......	28·08	2,199	60·5	51·0
(6)	7 12 30 „	......	......	28·18	2,098	61·0	51·0
	7 13 0 „	......	......	28·27	2,007	61·2	51·0
	7 13 30 „	......	......	28·40	1,876	61·3	51·2
	7 13 45 „	......	......	......	......	61·3	51·5
(7)	7 14 0 „	......	......	28·40	1,876	61·5	51·5
	7 14 30 „	......	......	28·40	1,876	61·8	51·5
	7 15 0 „	......	......	28·40	1,876	62·0	51·8
	7 15 30 „	......	......	28·40	1,876	62·2	51·8
	7 15 45 „	......	......	28·40	1,876	62·2	51·8
	7 16 0 „	......	......	28·43	1,846	62·2	51·8
(8)	7 16 30 „	......	......	28·50	1,776	62·4	51·8
	7 17 0 „	......	......	28·55	1,727	62·8	52·1
	7 17 30 „	......	......	28·59	1,688	62·5	52·5
	7 18 0 „	......	......	28·68	1,601	62·8	52·8
	7 18 30 „	......	......	28·68	1,601	63·1	52·8
(9)	7 19 0 „	......	......	28·70	1,582	63·1	53·0
	7 19 30 „	......	......	28·75	1,533	63·3	53·1
	1.	2.	3.	4.	5.	6.	7.

(1) Misty.
(2) Shoreham and Worthing.
(3) A beautiful view of the Downs.
(4) Near Newhaven.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
4·6	41·8	51·0						
5·1	41·7	51·0	......	......	......	......	40·5	
5·1	41·7	......	......	......	......	......	40·5	
5·1	41·7	......	......	......	......	......	41·5	
5·5	40·5	......	......	......	......	......	40·0	
5·5	40·5							
4·6	42·3	52·0						
6·2	41·6	......	......	......	......	......	41·0	
5·1	42·0	52·5	......	......	......	......	41·5	
4·4	43·7	52·7						
4·9	43·4							
4·7	44·4	......	......	......	......	......	48·0	
4·2	45·8	54·3						
4·0	46·1							
3·7	47·4	......	......	......	......	......	47·3	
3·2	47·9							
3·9	47·4							
4·1	47·2	55·5	......	......	......	......	46·7	
5·2	48·0							
5·8	45·7							
6·0	45·5	57·1	......	......	......	......	46·4	
6·5	44·6	57·1						
6·2	45·3							
8·0	42·9	58·7	......	......	......	......	46·0	
9·5	41·6							
9·0	42·5	......	......	......	......	......	45·5	
9·0	42·5							
8·7	42·7							
8·7	42·7	59·4						
9·5	41·6							
9·3	42·0							
9·6	42·0							
9·5	44·0	60·7	......	......	......	......	44·5	
10·0	42·3							
10·2	42·1							
10·1	42·4	......	......	......	......	......	44·0	
9·8	42·9	61·0						
10·0	42·9							
10·3	42·7							
10·2	43·0	......	......	......	......	......	43·5	
10·4	42·9							
10·4	42·9							
10·4	42·9	62·2						
10·6	42·7	......	......	......	......	......	43·0	
10·7	43·0							
10·0	44·0							
10·0	44·3							
10·3	44·0							
10·1	44·4	......	......	......	......	......	44·5	
10·2	44·5							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(5) Brighton seen.
(6) Sand out.
(7) Balloon entered the east current.
(8) Sand out.
(9) Sand out.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	7 20 0 p.m.	......	......	28·80	1,485	63·5	53·5
	7 20 30 „	......	......	28·80	1,485	63·5	54·1
	7 21 0 „	......	......	28·85	1,437	63·8	54·1
	7 21 30 „	......	......	28·90	1,388	64·1	54·5
(1)	7 22 0 „	......	......	29·00	1,290	64·3	54·5
	7 23 0 „	......	......	29·40	904	64·5	54·5
	7 24 0 „	......	......	29·40	904	65·5	55·5
	7 24 30 „	......	......	29·40	904	65·5	56·0
	7 25 0 „	......	......	29·40	904	65·6	56·0
	7 25 30 „	......	......	29·40	904	65·8	57·0
	7 26 0 „	......	......	29·30	994	66·1	56·5
	7 26 30 „	......	......	29·15	1,029	66·2	56·1
	7 27 0 „	......	......	29·08	1,092	66·2	55·7
	7 27 15 „	......	......	29·05	1,119	66·5	55·5
	7 27 30 „	......	......	29·02	1,273	66·8	55·0
	7 27 45 „	......	......	28·98	1,312	66·7	54·8
	7 28 0 „	......	......	28·95	1,341	66·1	54·8
	7 28 15 „	......	......	28·95	1,341	66·1	54·1
	7 29 0 „	......	......	28·95	1,341	66·5	54·5
	7 29 30 „	......	......	28·95	1,341	66·2	54·5
	7 30 0 „	......	......	29·05	1,231	66·2	54·5
	7 30 15 „	......	......	29·08	1,204	66·2	54·5
(2)	7 30 30 „	......	......	29·10	1,186		
	7 31 0 „	......	......	29·20	1,096	66·2	55·0
(3)	7 31 30 „	......	......	29·20	1,096	66·8	55·5
	7 32 0 „	......	......	29·20	1,096	66·8	55·0
	7 32 0 „	......	......	29·20	1,096		
(4)	7 32 30 „	......	......	28·95	1,341	66·2	54·1
	7 33 0 „	......	......	28·80	1,488	66·5	53·5
(5)	7 34 0 „	......	......	28·55	1,733	66·8	53·1
	7 34 15 „	......	......	28·40	1,882	66·2	52·1
	7 34 30 „	......	......	28·20	2,080	66·0	52·2
	7 34 45 „	......	......	28·15	2,129	65·8	52·2
	7 35 0 „	......	......	27·85	2,426	65·5	52·5
	7 35 30 „	......	......	27·72	2,555	65·1	52·5
	7 36 0 „	......	......	27·72	2,555	65·2	52·5
(6)	7 36 30 „	......	......	27·70	2,575	64·5	52·5
	7 36 45 „	......	......	27·65	2,625	64·0	52·5
(7)	7 37 0 „	......	......	27·65	2,625	63·8	55·0
	7 37 30 „	......	......	27·59	2,687	63·5	53·1
	7 38 0 „	......	......	27·62	2,657	63·2	53·1
	7 38 30 „	......	......	27·68	2,597	63·1	53·1
	7 38 45 „	......	......	27·70	2,577	63·1	53·7
	7 39 0 „	......	......	27·70	2,577	63·0	53·8
	7 40 0 „	......	......	27·78	2,497	63·0	53·8
(8)	7 40 30 „	......	......	27·80	2,477	63·0	53·8
	7 41 0 „	......	......	27·82	2,457	63·2	55·5
	7 42 0 „	......	......	28·08	2,197	63·5	53·2
	7 42 15 „	......	......	28·18	2,097	63·1	53·2
	7 43 0 „	......	......	28·35	1,927	63·5	53·0
	7 43 30 „	......	......	28·40	1,877	63·5	53·1
	1.	2.	3.	4.	5.	6.	7.

(1) We are moving parallel to the coast.
(2) Sand out.
(3) Very fine view of the Downs.
(4) Nearly over Lancaster Harbour.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
10·0	45·2	......	......	......	......	......	45·2	
9·4	46·2	63·6						
9·7	46·0							
9·6	46·5							
9·8	46·4	......	......	......	......	......	45·5	
10·0	46·2							
10·0	47·3							
9·5	48·2							
9·6	48·2	65·5						
8·8	49·8							
9·6	48·7							
10·1	48·0	......	......	......	......	......	48·5	
10·5	47·3							
11·0	46·6	......	......	......	......	......	48·0	
11·8	45·5							
11·9	45·2							
11·3	45·6	66·2						
12·0	44·4	......	......	......	......	......	45·0	
12·0	44·8							
11·7	45·1							
11·7	45·1	......	......	......	......	......	44·5	
11·7	45·1	66·3						
11·2	46·0							
11·3	46·4							
11·8	45·5	......	......	......	......	......	45·0	
12·1	44·4							
13·0	43·0	......	......	......	......	......	42·5	
13·7	42·1	67·0						
14·1	40·8							
13·8	40·9							
13·6	40·9							
13·0	41·8	......	......	......	......	......	42·0	
12·6	42·1							
12·7	42·2	......	......	......	......	......	42·5	
12·0	42·9							
11·5	43·0							
8·8	47·6							
10·4	44·4	63·4						
10·1	44·6	......	......	......	......	......	43·5	
10·0	44·6	......	......	......	......	......	44·0	
9·4	45·7							
9·2	46·0							
9·2	46·0							
9·2	46·0	62·9						
7·7	49·1							
8·3	44·4							
9·9	44·6							
10·5	44·2							
10·4	44·4							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(5) Flocks of sheep are huddling together.
(6) Can see the Isle of Wight, and Solent.
(7) Over the Downs.
(8) Smoke moving towards the coast.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	7 44 0 p.m.	......	......	28·45	1,827	63·7	53·0
(1)	7 44 30 "	......	......	28·56	1,716	63·8	52·8
	7 45 0 "	......	......	28·56	1,716	63·8	53·0
(2)	7 46 0 "	......	......	28·70	1,580	64·2	54·1
	7 46 30 "	......	......	28·75	1,532	64·2	54·5
(3)	7 46 45 "	......	......	28·80	1,483	64·2	54·8
(4)	7 47 0 "	......	......	28·80	1,483	64·2	54·8
(5)	7 48 0 "	......	......	28·80	1,483	64·2	55·1
(6)	7 48 30 "	......	......	28·80	1,483	64·2	55·5
	7 49 0 "	......	......	28·80	1,483	64·0	56·0
	7 49 30 "	......	......	28·80	1,483	64·2	56·0
	7 50 0 "	......	......	28·95	1,337	64·5	56·1
	7 50 30 "	......	......	29·00	1,289	64·5	56·0
	7 50 45 "	......	......	29·00	1,289	64·5	56·1
	7 51 30 "	......	......	29·05	1,241	64·5	56·1
	7 52 0 "	......	......	29·08	1,212	64·8	56·0
(7)	7 52 30 "	......	......	29·15	1,145	64·8	56·1
	7 53 30 "	......	......	29·25	1,049	64·8	56·1
	7 54 0 "	......	......	29·28	1,020	64·8	56·5
(8)	7 54 30 "	......	......	29·30	1,000	64·9	56·7
	7 55 0 "	......	......	29·30	1,000	65·0	56·8
(9)	7 56 30 "	......	......	29·30	1,000	65·0	56·8
	7 56 45 "	......	......	29·28	1,020	65·2	57·2
	7 57 0 "	......	......	29·30	1,000	65·0	57·2
(10)	7 57 15 "	......	......	29·27	1,029	65·2	56·8
	7 58 0 "	......	......	29·30	1,000	65·2	57·1
	7 58 30 "	......	......	29·30	1,000	65·2	57·1
(11)	7 59 0 "	......	......	29·30	1,000	65·2	57·1
	7 59 30 "	......	......	29·35	952	65·2	57·1
(12)	7 59 45 "	......	......	29·50	808	65·5	57·5
(13)	8 1 0 "	......	......	29·55	760	65·5	57·5
(14)	8 1 30 "						
(15)	8 2 0 "	......	......	29·45	856	65·2	57·2
(16)	8 3 0 "	......	......	29·38	923	66·1	57·0
	8 3 30 "	......	......	29·15	1,144	65·5	56·8
(17)	8 4 0 "	......	......	29·05	1,241	65·5	56·8
	8 4 30 "	......	......	29·00	1,290	65·5	57·0
(18)	8 5 0 "	.....	......	29·05	1,241	65·0	57·0
(19)	8 5 15 "	......	......	29·05	1,241	65·0	57·0
	8 6 0 "	......	......	29·10	1,192	65·1	57·1
(20)	8 6 30 "	......	......	29·15	1,144	65·1	57·1
	8 7 0 "	......	......	29·20	1,096	65·2	57·1
(21)	8 7 15 "	......	......	29·25	1,048	65·2	57·1
(22)	8 8 0 "	......	......	29·25	1,048	65·2	57·1
	1.	2.	3.	4.	5.	6.	7.

(1) Railway. (2) Can see Arundel.
(3) A fine park; Duke of Norfolk's. (4) Arundel Castle.
(5) Again within the influence of the East wind. (6) Not far from Bognor.
(7) Tinkling of sheep bells; the roads are remarkably white.
(8) Very wooded country.
(9) The scene was now almost fairy-like, the panorama seemed to be moving; the wind was S.E.
(10) Cries of "come down" distinctly heard, and the cheering cries of children heard above other sounds. (11) The wind is now E.; sea-breeze felt.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
10·7	44·1							
11·0	43·6							
10·8	44·0							
10·1	45·8	64·2	......	......	......	......	47·0	
9·7	46·5							
9·4	47·0							
9·4	47·0	......	......	......	......	......	47·5	
9·1	47·6							
8·7	48·4							
8·0	49·4	......	......	......	......	......	48·0	
8·2	49·3							
8·4	49·2	......	......	......	......	......	48·5	
8·5	49·0							
8·4	49·2							
8·4	49·2							
8·8	48·8							
8·7	49·0	64·9	......	......	......	......	49·0	
8·7	49·0							
8·3	49·7							
8·2	50·0							
8·2	50·0	......	......	......	......	......	50·0	
8·2	50·0							
8·0	50·7	......	......	......	......	......	50·5	
7·8	50·8							
8·2	49·9	......	......	......	......	......	50·8	
8·1	50·5							
8·1	50·5							
8·1	50·5							
8·1	50·5							
8·0	50·9							
8·0	50·9	65·5	......	......	......	......	51·0	
8·0	50·7							
9·1	49·6							
8·7	49·9							
8·7	49·9							
8·5	50·0	......	......	......	......	......	51·5	
8·0	50·4							
8·0	50·4							
8·0	50·5							
8·0	50·5							
8·1	50·5							
8·1	50·5	65·3						
8·1	50·5							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(12) Moving due West. (13) Over Dale Park, and moving towards Portsmouth.
(14) Sand out. (15) Very wooded country, with forests of wood.
(16) A pack of dogs barking at the balloon in the wildest state of excitement.
(17) Ducks and geese are scuttling away very much frightened.
(18) Packed up hygrometer. (19) A very extensive wood under us.
(20) Over a very extensive wood.
(21) We are apparently about 4 or 5 miles from the coast.
(22) Heard a bugle; Chichester was stated to be 5 miles from us, by a countryman to whom we spoke.

TABLE I.—Meteorological Observations made in the Twelfth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	8 9 0 p.m.	......	......	29·15	1,145	65·2	57·1
	8 9 30 „	......	......	28·72	1,561	64·5	56·1
	8 10 0 „	......	......	28·65	1,629	64·5	56·5
	8 10 15 „	......	......	28·65	1,629	64·2	55·8
	8 10 45 „	......	......	28·58	1,697	64·3	55·5
	8 11 0 „	......	......	28·58	1,697	64·5	55·5
	8 11 30 „	......	......	28·58	1,697		
	8 12 0 „	......	......	28·65	1,629	64·2	55·5
	8 13 0 „	......	......	28·75	1,532	64·2	55·2
(1)	8 14 0 „	......	......	28·75	1,532	64·2	56·0
	8 14 30 „	......	......	28·85	1,435	64·2	56·0
	8 15 0 „	......	......	29·10	1,190	63·8	56·2
	8 15 30 „	......	......	29·15	1,142	63·9	56·5
	8 16 0 „	......	......	29·20	1,094	64·2	56·5
(2)	8 16 15 „	......	......	29·25	1,046	64·2	57·0
	8 17 0 „	......	......	29·35	950	64·5	57·0
	8 17 30 „	......	......	29·35	950	64·5	57·0
	8 18 0 „	......	......	29·35	950	64·5	57·0
	8 18 15 „	......	......	29·42	883	64·8	57·0
	8 18 30 „	......	......	29·48	825	64·8	57·0
	8 19 0 „	......	......	29·52	789	64·8	57·2
	8 19 30 „	......	......	29·55	760	64·2	57·1
	8 20 0 „	......	......	29·55	760	65·5	57·1
	8 20 15 „	......	......	29·50	808	65·2	57·1
	8 20 45 „	......	......	29·48	825	65·2	57·2
	8 21 0 „	......	......	29·30	998	65·1	57·1
	8 22 0 „	......	......	29·05	1,239	64·8	56·1
	8 22 30 „	......	......	29·00	1,289	64·8	56·1
	8 23 0 „	......	......	28·78	1,502	64·5	56·1
	8 23 30 „	......	......	28·70	1,580	64·5	56·0
(3)	8 24 0 „	......	......	28·63	1,648	64·5	56·2
	8 25 0 „	......	......	28·58	1,696	64·0	55·3
	8 26 0 „	......	......	28·63	1,648	64·2	56·0
	8 27 0 „	......	......	28·71	1,570	64·2	56·0
	8 27 30 „	......	......	28·85	1,436	64·2	57·0
	8 28 0 „	......	......	29·10	1,196	64·2	56·5
	8 29 0 „	......	......	29·10	1,196	64·2	56·7
	8 30 0 „	......	......	29·30	1,004	64·2	57·1
	8 31 0 „	......	......	29·30	1,004	64·2	57·1
	8 31 30 „	......	......	29·50	812	64·5	57·1
	8 32 0 „	......	......	29·52	793	64·5	57·2
(4)	8 32 30 „	......	......	29·65	666	65·1	58·2
	8 33 0 „	......	......	29·53	780	65·1	58·2
	8 33 30 „	......	......	29·32	980	65·1	57·2
(5)	8 34 0 „	......	......	29·21	1,085	65·0	57·1
(6)	8 40 0 „						
	8 50 0 „	......	......	......	......	68·5	
	1.	2.	3.	4.	5.	6.	7.

(1) Goodwood Park visible; we shall go over it. (2) Bugle again.
(3) Packed up the gridiron thermometer.

Balloon Ascent, from the Crystal Palace, July 11, 1863.

...mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
8·1	50·5							
8·4	49·2							
8·0	49·2							
8·4	48·9							
8·8	48·3							
9·0	48·1							
8·7	48·4							
9·0	47·8							
8·2	49·3							
8·2	49·3							
7·6	49·9							
7·4	50·4							
7·7	50·1							
7·2	51·0	64·3						
7·5	50·8							
7·5	50·8							
7·5	50·8							
7·8	50·6							
7·8	50·6							
7·6	51·0							
7·1	51·2							
8·4	50·2							
8·1	50·5							
8·0	50·6							
8·0	50·5							
8·7	49·0							
8·7	49·0							
8·4	49·2							
8·5	49·0							
8·3	49·4	64·5						
8·7	48·1							
8·2	49·2							
8·2	49·2							
7·2	51·0							
7·7	50·1							
7·5	50·3							
7·1	51·2							
7·1	51·2							
7·4	51·0							
7·3	51·2							
6·9	52·6							
6·9	52·6							
7·9	50·7							
7·9	50·6							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(4) Over Goodwood Park; wooded country.
(5) Packed up instruments.
(6) On the ground.

TABLE I.—Meteorological Observations made in the Thirteenth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Thermometers. Dry.	Dry and Wet Thermometers. Wet.
	h m s	in.	°	in.	feet.	°	°
(1)	....	......	......	......	......	61·5	60·2
	4 50 0 p. m.	......	......	29·52	on the ground.	61·5	61·2
	4 51 0 ,,	......	......	......		61·3	61·1
(2)	4 52 0 ,,	......	......	29·51		61·3	61·1
	4 52 10 ,,	......	......	29·42		60·5	60·0
(3)	4 52 20 ,,	......	......	29·15	521	60·5	59·3
(4)	4 52 30 ,,	......	......	28·80	859		
	4 52 40 ,,	......	......	28·60	1,051	60·0	.....
	4 52 50 ,,	......	......	28·42	1,227	59·1	58·0
(5)	4 53 0 ,,	......	......	28·20	1,439	58·2	57·1
(6)	4 53 30 ,,						
(7)	4 54 0 ,,	......	......	27·95	1,681	57·5	56·2
(8)	4 54 30 ,,	......	......	27·70	1,823	56·5	55·5
	4 54 40 ,,						
(9)	4 55 0 ,,	......	......	27·42	2,095	56·0	56·0
(10)	4 55 20 ,,						
(11)	4 55 30 ,,	......	......	27·25	2,351	54·8	54·8
(12)	4 55 40 ,,						
(13)	4 56 0 ,,	......	......	27·05	2,589	54·0	54·0
	4 56 30 ,,	......	......	26·90	2,740	53·5	53·5
	4 57 0 ,,	......	......	26·80	2,845	54·2	54·2
	4 57 30 ,,	......	......	26·90	2,740	54·0	54·0
	4 58 0 ,,	......	......	26·95	2,790	54·2	54·2
(14)	4 58 30 ,,	......	......	27·05	2,589	53·5	53·5
(15)	4 59 0 ,,	......	......	......	(2,556)	53·2	53·2
(16)	4 59 30 ,,	......	......	......	(2,523)	53·7	53·5
(17)	5 0 0 ,,	......	......	27·15	2,488	55·0	55·0
(18)	5 0 30 ,,						
(19)	5 1 0 ,,	......	......	27·03	2,610	55·0	55·0
	5 1 15 ,,						
	5 1 30 ,,	......	......	26·95	2,700	54·5	54·5
	5 2 0 ,,	......	......	26·80	2,850	54·2	54·2
(20)	5 2 15 ,,						
(21)	5 2 30 ,,	......	......	26·75	2,900	53·9	53·8
	5 2 45 ,,						
	5 3 0 ,,	......	......	26·75	2,900	53·5	53·3
(22)	5 3 10 ,,						
(23)	5 3 15 ,,						
	5 3 30 ,,	......	......	26·68	2,967	53·5	53·0
	5 4 0 ,,	......	......	26·70	2,945	53·5	52·5
(24)	5 5 0 ,,	......	......	26·75	2,890	53·7	52·2
(25)	5 6 0 ,,	......	......	26·85	2,750	53·5	53·2
(26)	5 7 0 ,,						
(27)	5 7 30 ,,	......	......	27·10	2,535	53·5	53·2
	1.	2.	3.	4.	5.	6.	7.

(1) Sky overcast, wind S. by E.
(2) Drops of rain as large as fourpenny pieces.
(3) Balloon left the earth. (4) Entered clouds.
(5) Earth out of sight on three sides; Crystal Palace still visible.
(6) In clouds; clouds very light; earth entirely out of sight.
(7) Gas let out; clouds very light. (8) Gas let out; very cloudy.
(9) Gas very cloudy. (10) Train heard.
(11) In dry cloud. (12) In white cloud.
(13) Darker above than below. (14) In dense fog.

Balloon Ascent, from the Crystal Palace, July 21, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
1·3	59·0	......	......	......	......	......	......	59·5
0·3	59·6							
0·2	60·9							
0·2	60·9							
0·5	59·5							
1·2	58·1							
......	......	60·0						
1·1	56·9							
1·1	56·1							
1·3	54·9							
1·0	54·5	56·5						
0·0	56·0							
0·0	54·8							
0·0	54·0							
0·0	53·5	53·5						
0·0	54·2	54·0						
0·0	54·0							
0·0	54·2	......	......	......	......	......	......	54·5
0·0	53·5							
0·0	53·2							
0·2	53·3							
0·0	55·0							
0·0	55·0	55·0	......	......	......	......	......	55·0
0·0	54·5							
0·0	54·2	......	......	......	......	......	......	54·0
0·1	53·7	53·8						
0·2	53·1	......	......	......	......	......	......	53·0
0·5	52·5							
1·0	51·5							
1·5	50·7	......	......	......	......	......	......	52·0
0·3	52·9							
0·3	52·9							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(15) Gas getting clearer. (16) Sand out. (17) Hammering heard.
(18) Hum of London heard; bell tolling. (19) Heard railway whistle.
(20) Clouds above darker than those below; can see the white edge of lower cloud.
(21) Out of cloud.
(22) Earth visible through a break in the clouds. (23) Docks visible below.
(24) Docks and River Thames visible; over Greenwich; ships visible.
(25) Over West India Docks.
(26) In open space; lower clouds moving N.E., and much faster than we are.
(27) Wind S.W.; moving N.E.

TABLE I.—Meteorological Observations made in the Thirteenth

References to Notes.	Time.	Siphon Barometer. Reading corrected and reduced to 32° Fahr.	Siphon Barometer. Att. Therm.	Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther- Dry.	Dry and Wet Ther- Wet.
	h m s	in.	°	in.	feet.	°	°
	5 7 45 p.m.	……	……	27·20	2,440	54·2	53·5
	5 8 0 „	……	……	27·30	2,340	54·2	53·5
(1)	5 8 15 „	……	……	27·35	2,290	54·2	53·5
(2)	5 8 30 „	……	……	27·50	2,133	55·1	54·2
(3)	5 8 45 „						
(4)	5 9 0 „	……	……	27·60	2,020	55·0	54·2
	5 9 30 „	……	……	27·78	1,840	55·5	54·1
	5 9 45 „	……	……	27·80	1,820	55·5	54·0
(5)	5 10 0 „	……	……	……	……	……	……
	5 10 30 „	……	……	28·00	1,635	56·0	55·1
(6)	5 10 45 „	……	……	……	……	56·2	55·1
	5 11 0 „	……	……	28·20	1,430	56·2	55·8
(7)	5 11 30 „	……	……	28·33	1,300	56·2	56·0
(8)	5 12 0 „	……	……	……	(1,120)	57·2	56·5
(9)	5 12 15 „	……	……	28·70	1,030	57·8	……
(10)	5 12 30 „						
	5 13 0 „	……	……	28·80	859		
	5 13 30 „	……	……	28·70	955		
	5 14 0 „	……	……	28·60	1,051	57·2	57·2
	5 14 30 „	……	……	28·50	1,147	57·5	57·5
(11)	5 15 0 „	……	……	28·40	1,241	57·5	57·5
	5 15 15 „	……	……	28·05	1,579	56·2	56·2
	5 15 30 „	……	……	27·80	1,739	55·5	55·5
	5 15 45 „	……	……	27·75	1,789	54·8	54·8
(12)	5 16 0 „	……	……	27·65	1,890	54·2	54·2
	5 16 15 „	……	……	27·30	2,240		
	5 16 30 „	……	……	27·30	2,240	……	……
	5 17 0 „	……	……	……	……	54·2	54·0
	5 17 30 „	……	……	27·10	2,526	54·0	53·5
	5 18 0 „	……	……	26·90	2,732	55·0	54·0
	5 18 30 „	……	……	26·70	2,938		
	5 19 0 „	……	……	26·55	3,086	53·5	53·0
(13)	5 19 30 „	……	……	26·42	3,220	53·0	52·2
	5 20 0 „	……	……	26·40	3,242	53·2	52·0
(14)	5 20 30 „	……	……	26·35	3,298	53·2	52·5
(15)	5 20 45 „	……	……	26·38	3,256		
	5 21 0 „	……	……	26·39	3,234	53·5	52·1
(16)	5 21 30 „	……	……	26·40	3,218	52·5	51·8
	5 22 0 „	……	……	26·50	3,138	52·2	51·5
(17)	5 22 30 „	……	……	26·50	3,138	52·2	52·2
(18)	5 23 0 „	……	……	26·70	2,924		
	5 23 15 „	……	……	26·75	2,870	52·2	52·2
	5 23 30 „	……	……	26·95	2,654		
(19)	5 24 0 „	……	……	27·30	2,386	54·0	53·5
	5 24 30 „	……	……	27·45	2,234		
	1.	2.	3.	4.	5.	6.	7.

(1) In cloud.
(2) Over high road; scud below moving apparently much faster than the balloon.
(3) See the earth through a thin layer of cloud.
(4) Over a field; detached clouds below; we are moving in an opposite direction to that in which we were moving recently.
(5) Scud below moving very fast.
(6) Passing below lower stratum; over River Lea.
(7) Over Walthamstow; carts visible.
(8) Nearly over Victoria Park.
(9) Over East London Cemetery.
(10) Lowering grapnel.

Balloon Ascent, from the Crystal Palace, July 21, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
0·7	52·8	54·2						
0·7	52·8							
0·7	52·8							
0·9	53·3							
0·8	53·4	55·0						
1·4	52·7							
1·5	52·5							
......	......	......	......	......	......	......	.....	53·0
0·9	54·3							
1·1	54·1	56·2						
0·4	55·4							
0·2	55·8							
0·7	55·8							
......	......	57·8						
0·0	57·2							
0·0	57·5							
0·0	57·5	57·5	......	......	......	......	......	58·0
0·0	56·2							
0·0	55·5							
0·0	54·8							
0·0	54·2	54·2						
......	......	......	......	......	......	......	......	54·5
0·2	53·8	54·3						
0·5	53·0							
1·0	53·0							
0·5	52·5							
0·8	51·4							
1·2	50·8							
0·7	51·8	......	......	......	......	......	......	51·5
1·4	50·7							
0·7	51·1							
0·7	50·8							
0·0	52·2							
0·0	52·2	......	......	......	......	......	......	52·0
0·5	53·0	54·1						
8.	9.	10.	11.	12.	13.	14.	15.	16.

(11) In fog. (12) In cloud.
(13) Clouds on same level as ourselves; some below; darker above; gas thick and opaque railway whistle heard. (14) Large masses of cumulus cloud below; light below.
(15) Light below; dark above. (16) In fog.
(17) Fine rain falling; grapnel visible plainly; misty all round.
(18) In wetting fog.
(19) Very fine rain falling; clouds blackish below; earth visible; water dropping from the balloon; scud below.

TABLE I.—Meteorological Observations made in the Thirteenth

References to Notes.	Time.	Siphon Barometer.		Aneroid Barometer, No. 2.	Height above sea-level.	Dry and Wet Ther-	
		Reading corrected and reduced to 32° Fahr.	Att. Therm.			Dry.	Wet.
	h m s	in.	°	in.	feet.	°	°
	5 25 0 p.m.	......	......	27·50	2,180	55·0	54·2
	5 26 0 „	......	......	27·70	1,960	55·5	54·1
(1)	5 26 30 „						
(2)	5 27 0 „	......	......	28·00	1,626		
(3)	5 28 0 „	......	......	28·60	1,044	59·0	59·0
	5 28 30 „	......	......	28·65	995	61·0	61·0
	5 29 0 „	......	......	28·66	987	61·2	61·2
(4)	5 29 30 „	......	......	28·70	948	61·1	61·1
	5 30 0 „	......	......	28·75	900	61·5	61·5
	5 30 30 „	......	......	28·75	900	61·5	61·5
	5 31 0 „	......	......	28·95	706	61·8	61·8
(5)	5 31 30 „	......	......	29·00	651		
	5 32 0 „	......	......	29·00	651	61·5	61·5
	5 32 30 „	......	......	28·90	755		
	5 32 45 „	......	......	28·72	929	60·5	60·5
(6)	5 33 0 „	......	......	28·45	1,179		
	5 33 15 „	......	......	28·33	1,300	58·5	58·5
(7)	5 33 30 „						
(8)	5 34 0 „	......	......	27·90	1,714	57·2	57·2
(9)	5 34 15 „	......	......	27·60	1,960	57·5	57·2
	5 34 30 „	......	......	27·60	1,960	57·5	57·5
	5 34 45 „	......	......	27·60	1,960	57·5	57·5
(10)	5 35 0 „	......	......	27·68	1,898	57·5	57·5
	5 35 30 „	......	......	27·78	1,801	57·8	57·8
(11)	5 35 45 „	......	......	27·80	1,780	58·5	58·5
(12)	5 36 0 „	......	......	28·00	1,635	58·9	58·9
(13)	5 36 30 „	......	......	28·18	1,455	58·6	58·6
(14)	5 37 0 „	......	......	28·30	1,330	59·2	59·0
	5 37 30 „	......	......	28·50	1,131	59·5	59·5
	5 37 45 „	......	......	28·60	1,041		
(15)	5 39 0 „	......	......	28·65	996	60·0	
	5 39 45 „						
	5 40 0 „	......	......	28·70	951	60·9	
	5 41 0 „	......	......	28·75	906	61·3	
	5 42 0 „	......	......	29·05	636	61·5	
	5 43 0 „	......	......	29·35	313	61·5	
(16)	5 45 0 „	......	......	29·58	ground	61·5	60·5
	1.	2.	3.	4.	5.	6.	7.

(1) In black cloud; earth invisible; darker below than above; gas beautifully clear; can see netting through the balloon.
(2) The drops of rain are very minute, as fine as pins' points.
(3) In clouds; grapnel scarcely visible.
(4) Still in cloud; can hear the tinkling of bells; can hear the noise made by the rain pattering on the trees of Epping Forest.
(5) Can see the road through the Forest; scud below; road nearly invisible.
(6) Scud far below. (7) Earth invisible; clouds above darker than below.
(8) Packed up Daniell's Hygrometer. (9) Gas thick and opaque; grapnel invisible.
(10) The grapnel and half of the rope are invisible.

Balloon Ascent, from the Crystal Palace, July 21, 1863.

mometers (free).		Negretti and Zambra's Gridiron Thermometer.	Dry and Wet Thermometers (aspirated).				Hygrometers.	
Diff.	Dew-point.		Dry.	Wet.	Diff.	Dew-point.	Daniell's. Dew-point.	Regnault's. Dew-point.
°	°	°	°	°	°	°	°	°
0·8	53·4							
1·4	52·7							
0·0	59·0	59·2						
0·0	61·0							
0·0	61·2							
0·0	61·1	......	......	......	......	......	......	61·5
0·0	61·5	61·6						
0·0	61·5							
0·0	61·8	62·0						
0·0	61·5							
0·0	60·5							
0·0	58·5							
0·0	57·2	57·3						
0·3	56·9							
0·0	57·5							
0·0	57·5							
0·0	57·5	57·5						
0·0	57·8							
0·0	58·5							
0·0	58·9							
0·0	58·6	58·7						
0·2	58·8							
0·0	59·5							
1·0	59·5							
8.	9.	10.	11.	12.	13.	14.	15.	16.

(11) The grapnel is just visible; rain pattering on the balloon.
(12) Rain-drops about $\frac{1}{16}$th of an inch in diameter.
(13) Earth visible; scud below moving at a greater rate than we are.
(14) In cloud; very dark; earth invisible; wind blowing in my face.
(15) Changed direction; passing over Wood; can see sheep clearly.
(16) Grapnel dragged through two trees, breaking off branches, &c., then through a pond, and finally caught in the bank. The descent was effected in a corn-field, and various efforts were made to bring the balloon out; but owing to the strength of the wind, the united strength of ten or twelve men was insufficient to get it over the hedge and keep it there.

§ 4. Adopted Temperatures of the Air, the Wet-Bulb, and the Dew-Point, in Five Balloon Ascents.

Table II.—Showing the adopted Reading of the Barometer, calculated Height above the Sea, Temperature of the Air, Temperature of the Wet-bulb Thermometer, and Temperature of the Dew-point in the ninth, tenth, and eleventh Ascents.—Ninth Ascent.—March 31.

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°	h m s	in.	feet.	°	°	°
4 11	29·72	420	49·8	44·2	38·2	5 33	15·78	16809			
14	29·72	420	49·2	44·2	38·8	34	16·83	15149	7·5		
16	29·39	780	47·5	41·3	34·5	35	16·88	15080	8·2		
17	29·10	1048	47·2	40·8	33·7	37	16·88	15080			
18	28·60	1515	46·0	38·1	29·1	38	16·58	15556	11·1	9·1	− 6·4
20 30	....	....	38·6			41	16·57	15565	9·1	6·2	− 6·3
21	26·56	3507	37·5	33·0	26·8	42	16·37	15872	9·3	5·1	−27·5
21 30	26·36	3698	38·5	32·0	23·2	42 30	16·47	15714	9·1	5·2	−35·1
23	25·31	4771	37·0	30·0	20·1	43	16·13	16080	9·1	5·1	−26·0
24	24·82	5296	35·5	29·2	19·5	45	16·13	16080	9·1	5·1	−26·0
25	24·22	5937	34·3	26·1	11·6	46	16·17	16080	8·0	5·1	− 7·4
27	23·52	6251	33·2	26·0	11·6	47	16·17	16080			
27 30	23·22	7035	33·0	25·1	9·3	47 40	16·17	16080	7·2	3·1	−28·7
28	22·92	7380	32·6	24·9	8·2	49	16·37	15847	7·2	3·1	−28·7
29	22·75	7557	32·1	24·8	7·9	50	....	(15775)	7·2	3·1	−28·7
32	21·63	8872	28·5			52	16·47	15630	7·0	3·0	−28·1
33	21·33	9218				52 30	16·57	15489			
35	20·63	10047	27·3	20·2	−12·5	53	16·77	15227			
40	18·73	12536	21·1			54	16·97	14965	7·0	6·0	− 1·8
41	18·33	13070	19·1	10·1	−55·9	55	17·17	14622	7·0		
43	17·34	14481	15·1	6·1	−63·6	56	17·37	14325	8·5	7·0	− 4·6
44	16·84	15198	14·2	5·1	−63·5	56 30	17·37	14325	9·0	7·0	− 8·5
44 30	16·49	15738	12·2	4·2	−58·0	57	17·88	13614	10·8	7·1	−21·5
45	....	(15793)	12·2	4·0	−58·2	58	18·27	13077	11·7	8·4	−17·4
46 30	15·95	16669	11·1	5·2	−40·7	58 30	18·47	12797	12·2	10·1	− 6·2
47	15·63	17060	9·0	2·0	−52·4	59	18·87	12232			
48	15·45	17451	9·0	3·0	−43·6	6 1	19·28	11674	13·5	11·1	− 7·5
49	15·35	17616	8·5	3·0	−39·7	2	19·47	11486	14·5	11·2	−14·4
49 30	14·86	18475				3	19·87	10917			
50	14·96	18304	11·1	7·2	−23·3	5	20·97	9570	19·0		
51	15·06	18123	11·0	7·1	−23·4	8	22·38	7907	21·2	17·0	−11·8
52	15·46	17400				9	22·78	7443	21·5		
58 30	15·67	17097	12·1	9·1	−14·2	9 30	....	(7050)	22·2	18·0	− 9·7
59 30	15·67	17097				10	23·48	6657	23·0	19·5	− 2·4
5 2	15·36	17636	11·0	8·0	−15·2	11	23·78	6279	24·2	20·5	− 1·3
4	14·96	18293	10·5	6·0	−29·0	11 30	24·18	5901	24·8	21·0	0·0
6	14·66	18730	9·3	2·5	−50·3	12	24·38	5696	25·1	21·2	+ 9·7
6 30	14·62	18795	8·2	2·0	−46·0	13	24·77	5273	25·5	22·0	3·5
7	....	....	7·0	2·5	−32·6	14	....	(4910)	25·9	22·0	2·2
8 50	14·37	19197				14 30	25·29	4729	26·9	22·0	1·7
10	14·27	19356	3·0	− 0·5	−28·7	15	25·57	4441	28·0	23·0	3·3
12	13·47	20865				16	25·87	5168			
14	13·87	20076				17	26·48	3528	28·2	24·4	13·9
15	13·82	20136				19	26·87	3143	28·5	26·1	16·9
16	13·68	20374	2·0	− 0·5	−20·6	20	27·07	2950	29·5	26·2	15·1
20	13·18	21331	2·0	− 0·1	−17·0	21	27·46	2570	30·0	27·2	18·4
23	13·48	20749				22	27·96	1908	30·0	27·5	19·7
24	13·38	20910	1·0	− 3·0	−35·0	22 30	28·16	1724	30·9	27·5	18·4
25	12·88	21868	0·5	− 3·5	−35·7	23	28·36	1590	31·5	28·0	19·9
26	12·78	22068				24	28·86	1260	32·2	28·5	20·0
27	12·38	22884	0·5	− 4·0	−35·4	25	29·06	1070	32·8	29·0	20·4
31	15·98	16486	3·1			25 30	29·50	893	35·0		
32	16·09	16309	4·1			30	29·89	ground	42·0		

Between $4^{h}\ 27^{m}$ and $5^{h}\ 56^{m}$ I failed in obtaining any deposition of dew on either Daniell's or Regnault's hygrometer, but the wet-bulb acted very satisfactorily during these times, and indicated the very low readings inserted in the Table.

TABLE II. (*continued.*)—TENTH ASCENT.—April 18.

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°	h m s	in.	feet.	°	°	°
0 12	29·80	....	61·0	55·2	50·2	1 55	14·05	20338			
15	29·80	....	59·5	53·5	48·3	56	14·05	20338			
1 13	29·66	....	60·8	54·5	49·1	2 0	13·75	20943	13·0	5·0	−57·1
14	29·66	....	61·5	54·2	47·8	2	14·05	20428			
17−	29·17	1030	59·2	54·0	48·4	9	13·65	21120	14·2		
17+	28·57	1603	57·2	51·1	45·5	10	....	....	15·0	3·0	90·0
18	27·97	2185	56·0	50·5	45·4	11	....	....	14·5		
18 30	....	(2380)	55·2	49·0	43·1	12	13·35	21646	13·0		
19	27·57	2575	54·0	48·0	42·2	13	13·30	21760			
20	26·75	3555	49·2	43·0	36·4	14	13·30	21760	16·5		
21 10	25·79	4392	47·2	41·0	34·1	15	13·25	21869	..	..	13·2
22 30	24·50	5759	41·2	35·1	27·5	15 30	13·20	22041	13·0	6·2	−69·7
24	....	....	40·5	37·0	33·6	22 30	12·75	22954	12·0	0·0	−97·2
24 15	23·90	6420	39·0			27	12·60	23258	12·3		
24 30	23·61	6744	37·0	35·2	32·6	28	....	23460	12·0		
25 30	23·21	7180	34·5	33·2	31·1	28 30	12·50	23460	12·0		
26	22·77	7694	32·8			29	12·50	23461			
27 30	22·70	7764				29 30	12·48	23500			
29	20·85	10020	32·0	25·8	12·1	30	12·50	23460			
29 30	20·63	10342				30 30	13·35	23753	12·5	0·5	−92·8
30	20·12	11055	31·5	24·2	5·9	31	12·45	23539	12·2		
32	19·13	12259	23·2			33	12·65	23109	12·1		
32 30	....	(12600)	23·0			33 10	12·75	22907	12·5	1·0	−88·4
33	....	....	23·0			33 30	13·35	21765			
34	18·35	13340	23·2			33 45	13·55	21381			
34 10	17·95	14030	21·0			34	13·65	21189			
35	....	(14600)	21·0			37 30	16·64	15998	15·7	7·0	−55·6
35 30	17·24	14986	20·0			38 30	17·24	14967			
40	16·25	16504	17·2	13·0	−19·0	39	....	(14670)	16·7	8·8	−51·4
42	15·86	17057	12·0	6·0	−20·6	40	17·64	14311			
43	15·81	17140	12·1	5·1	−49·3	40 30	18·14	13590	16·5	10·0	−39·7
47	15·46	17749	12·0	5·0	−49·5	41 30	....	....	17·0	14·5	− 4·5
48	15·81	18886	12·0	4·5	−53·8	42	19·94	11100	18·0	15·5	− 3·2
49	14·81	18886	12·0	4·9	−50·3	43	20·04	11003	20·2	18·1	+ 4·6
50	....	(19140)	11·8	5·7	−41·6	43 30	20·24	10785	24·2	19·0	−10·6
52	14·37	19644	10·5			44	20·94	9609	26·1	20·0	−10·4
52 50	14·15	20163	11·5			48	....	ground	..	20·0	
54	14·15	20163	11·3	6·0	−35·2						

The rope connecting us with the earth broke; I was consequently thrown, by this sudden departure, among the instruments, and both Daniell's and Regnault's Hygrometers were broken; I was therefore solely dependent on the Wet-bulb Thermometer, whose action was throughout good.

N.B. From all the observations of the temperature of the air, the wet-bulb, and the dew-point in the preceding Tables, a determination was made of these elements, with the corresponding readings of the barometer and heights. Some of the numbers in the column for heights have been interpolated when either of these elements have been observed without a corresponding observation of the barometer. The numbers thus found are within brackets. The results are contained in the Tables in pp. 472–475.

Table II. (*continued.*)—Eleventh Ascent.—June 26.

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°
1 2	29·70	ground			
3	....	....	66·0	57·0	49·8
4	29·15	884	65·0	56·0	48·7
4 30	28·57	1445	62·0	54·0	47·2
6	....	....	61·8	53·5	46·4
6 15	28·36	1660	61·5	53·1	45·9
6 30	27·86	2150	59·5	51·5	44·4
7	27·36	2651	57·2	51·2	45·7
7 20	....	(3029)	55·0	49·8	44·9
8	....	(3785)	51·0		
8 10	27·45	(3974)	50·5		
8 50	25·27	4729	48·5		
9	24·87	5264	47·0	40·0	32·2
10	24·58	5578	44·0		
11	23·79	6477			
13	....	(7300)	41·2	31·0	18·1
13 30	22·80	7510	39·0	29·2	16·3
14	....	(7940)	37·2	26·1	10·4
15	21·82	8796			11·0
15 20	....	(8827)	36·0	26·1	11·3
16	21·65	8888			
16 30	20·75	9298	31·2	..	8·0
17	20·65	9800	31·5		
17 15	20·20	10800			
17 30	20·22	10804			
17 45	19·93	11204	30·0		
18	19·75	11478			
18 20	19·83	11341	31·1		
19	19·23	12177			
19 30	19·05	12459			
20	18·83	12743	30·5	30·5	30·5
20 10	18·53	13173			
21	18·13	13764			
21 10	18·03	13913	31·0	31·0	31·0
23	17·63	14530	32·0	29·0	22·1
24	17·13	15295			
25	16·93	15598	30·0	29·0	25·9
25 20	16·83	15757	30·0	29·0	25·9
26	16·73	15935	29·0	26·0	15·2
27	16·63	16079	30·0	26·0	13·4
28	16·63	16079	32·0	27·6	12·1
29	16·53	16274	32·0	27·0	(11·3)
29 20	....	(16274)	33·0	28·5	19·5
29 30	16·53	16274			
29 45	16·40	16486	35·0	30·0	22·0
30	....	(16548)	35·0	29·8	21·5
31	16·23	16796			
31 30	16·15	16870	34·5	29·2	17·4
32	16·03	17144	34·5		
32 10	16·03	17144	34·5		
32 30	16·03	17144	34·5		
33	15·93	17242			
33 30	15·88	17339	34·3		
34	15·83	17479	34·2	28·1	17·4
35	15·83	17479			
35 30	15·49	18053	33·0	23·1	3·3

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°
1 36	15·33	18291			
36 20	15·23	18435	29·2	21·2	− 7·8
36 30	15·23	18435	..	..	−10·1
36 45	15·13	18555	26·2	21·0	− 5·0
37	15·15	18560	25·0	19·0	−14·1
38	....	(18790)	25·0	18·5	−17·4
39	14·83	19018	21·8		
40	14·73	19178	20·6	16·2	−14·6
40 40	....	(19420)	20·5	16·0	−15·5
41	14·53	19544	..	..	−11·0
41 10	14·53	19544	20·0	16·0	−12·5
41 45	14·33	19909	20·5	16·0	−15·5
42	14·23	20167	21·1	16·0	−19·0
42 30	14·24	20167	21·1	16·0	−19·0
43	13·95	20648	21·0	16·0	−18·4
43 30	....	....	19·1	16·1	− 5·9
44	13·94	20648	20·0	16·0	−12·5
45	13·84	20854	..	..	−13·0
46	13·64	21266	22·0	16·1	−22·8
47	13·59	21357	22·0	16·0	−23·6
48	13·34	21978			
49	13·24	22053			
50	13·24	22053	22·0	16·0	−23·6
51	13·20	22073	21·8	16·0	−22·2
53	13·14	22105			
53 30	13·14	22105	19·2	16·1	− 6·5
53 40	....	....	..	..	− 3·5
54	12·89	22664	18·5		
54 30	....	(23023)	18·5	16·0	− 2·5
54 40	12·66	23143	18·0		
54 50	....	(23200)	17·0	16·2	+ 2·5
55	13·04	22965	18·5	18·0	+14·3
58	13·14	22168	19·1	..	+ 2·0
58 30	13·54	21457	23·0	..	+ 2·0
59	13·65	21302			
2 0	13·85	20934	26·1	20·6	0·0
1	14·25	20167			
2	14·25	20167	26·1	22·0	+ 1·2
2 30	14·25	20167	26·1		
2 45	14·25	20167	29·2		
3	14·44	19901	31·0	24·0	+ 5·1
4 30	14·64	19367	23·0	22·0	
4 45	....	....	..	..	15·0
5	14·44	19901	23·0	21·5	15·8
6 10	....	....	23·0	21·0	12·7
6 20	14·34	20025	23·0		
6 45	....	....	25·0	23·0	12·0
7	14·04	20630	28·9	23·0	1·5
7 30	14·34	20025	28·1	23·7	5·6
8	14·64	19367	27·5	23·4	5·4
8 30	14·84	19089			
9	15·04	18746	28·0	24·0	7·6
9 30	....	....	29·2	23·1	1·1
10	15·34	18235			
10 15	....	....	29·0	23·5	4·6
10 20	....	....	29·0	23·0	1·2

TABLE II. (*continued*).—ELEVENTH ASCENT.—June 26 (*continued*).

Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.	Time of observation. P.M.	Reading of the Barom. reduced to 32° F.	Height above the level of the sea.	Temp. of the Air.	Temp. of the Wet-bulb.	Temp. of the Dew-point.
h m s	in.	feet.	°	°	°	h m s	in.	feet.	°	°	°
2 10 45	15·54	17888	29·5	24·5	7·5	2 16 30	20·05	....	33·0	27·5	16·4
11	16·04	17422	29·5	24·5	7·5	17	20·44	10508	33·0	27·0	14·9
11 15	16·24	16776	31·0			18	20·77	10011	33·0	26·5	13·4
11 30	16·35	16594				19	20·77	10011	33·5	26·0	11·8
11 45	....	....	31·5	26·0	12·2	19 30	20·89	9917			
12	16·44	16412	32·0	26·2	12·1	19 45	21·29	9402			
12 30	....	....	32·5	26·2	12·6	20 20	21·49	9148	33·5	26·0	11·8
13	16·84	15762	32·0	27·0	15·4	20 30	22·33	8107	34·5	27·2	14·9
13 15	16·95	15602				21	24·25	(5870)	38·0		
13 30	16·99	15521	31·5	27·0	15·7	22	24·72	5319	39·2	33·0	24·8
14	17·39	14892	33·0			23	....	....	42·0	35·1	26·6
14 15	....	....	33·0	27·0	14·9	24	....	....	43·0	37·0	29·8
14 30	17·64	14501				25	25·81	4138			
14 45	17·84	14197	33·0			25 30	26·60	3394	46·2	43·1	39·6
14 50	18·04	13896	33·0	29·2	21·6	26	26·70	3293	47·0	43·0	38·5
15	....	....	33·0	29·2	21·6	27	28·18	1810			
15 10	18·74	12865	33·0			27 30	28·76	1259			
15 30	19·04	12433	33·0			28	29·26	779			
15 45	....	....	33·0	29·5	22·5	28+	30·10	ground	66·5	60·0	54·7
16	19·77	11412									

The readings of the Gridiron thermometer were taken occasionally only in the twelfth and thirteenth ascents, as checks on the accuracy of temperature as shown by the dry-bulb thermometer, and no combination of readings is necessary in these ascents for adopted temperatures, &c., and therefore in subsequent calculations the readings as they appear in Table I. are used.

§ 5. VARIATION OF TEMPERATURE OF THE AIR WITH HEIGHT.

Every reading of temperature in the preceding Tables, or the means of small groups of readings when observations have been taken near to each other, was laid down on diagrams; all these points were joined, and a curved line was drawn to pass through or near to them, giving them equal weight, and by this means every change was made evident to the eye.

In all these curves there were parts of the same curve showing a gradual decrease of temperature with increase of elevation, and a gradual increase of temperature with decrease of elevation. The curve of which these were parts was assumed to be the true curve of normal temperature freed from disturbing causes, and the deviation from this curve indicated the places of disturbance and their amounts. The next step was the reading from these curves the temperature at every thousand feet, and in this way the next Tables were formed.

The numbers in the first column show the height in feet, beginning at 0 feet and increasing upwards; the numbers in the second column show the interval of time in ascending to the highest point; the notes in the third column show the circumstances of the observations; the numbers in the fourth and fifth columns the observations and the approximate normal temperatures of the air; and those in the next column the difference between the two preceding columns, or the most probable effect of the presence of cloud or mist on the temperature, or of other disturbing causes in operation.

The next group of columns are arranged similarly for the descent, and the other groups for succeeding ascents and descents.

TABLE III.—Showing the Temperature of the Air, as read off the curve drawn through the observed temperatures, and as read off the curve of most probable normal temperature, called adopted temperature, and the calculated amount of disturbance from the assumed law of decrease of temperature.

NINTH ASCENT.

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
March 31.	From $4^h\ 10^m$ to $5^h\ 27^m$ p.m.	Clear blue sky.	°	°	°	From $5^h\ 27^m$ to $6^h\ 30^m$ p.m.	Cloudless.	°	°	°
23000			1·0	0·0	+ 1·0			1·0	0·0	+ 1·0
22000			1·5	1·0	+ 0·5			1·0	0·3	+ 0·7
21000			2·0	2·2	− 0·2			1·4	1·1	+ 0·3
20000			3·0	4·0	− 1·0			1·7	1·8	− 0·1
19000			6·5	5·9	+ 0·6			1·9	2·2	− 0·3
18000			10·7	8·0	+ 2·7			2·2	3·0	− 0·8
17000			9·8	9·9	− 0·1			2·6	4·0	− 1·4
16000			12·0	12·0	0·0			5·5	5·5	0·0
15000			14·3	14·0	+ 0·3			6·9	7·2	− 0·3
14000			16·0	16·0	0·0			10·4	9·4	+ 1·0
13000			18·8	18·0	+ 0·8			12·0	11·4	+ 0·6
12000			18·0	20·3	− 2·3			13·4	13·5	− 0·1
11000			22·0	22·9	− 0·9			15·7	15·5	+ 0·2
10000			26·3	25·6	+ 0·7			17·8	17·4	+ 0·4
9000			28·1	27·9	+ 0·2			19·3	19·0	+ 0·3
8000			30·8	30·1	+ 0·7			21·0	21·0	0·0
7000			33·0	32·3	+ 0·7			22·8	22·8	0·0
6000			35·8	34·5	+ 1·3			24·7	24·5	+ 0·2
5000			36·0	36·7	− 0·7			25·9	26·0	− 0·1
4000		Misty.	38·2	38·9	− 0·7			28·0	27·7	+ 0·3
3000			39·6	41·0	− 1·4			29·2	29·5	− 0·3
2000			44·0	44·0	0·0			30·0	31·5	− 1·5
1000			47·2	47·0	+ 0·2			33·5	34·8	− 1·3
0			..	51·9	....			42·0	42·0	0·0

March 31.—The sky was clear, and the amounts of deviation of temperature on either side of the adopted curve-line were generally small, both during the ascent and descent of the balloon.

On ascending, there was a curious warm stratum of air between 17,000 and 19,000 feet high, and a similar one was met with on descending, between 15,000 and 15,500 feet high.

TABLE III. (*continued.*)

TENTH ASCENT.

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
April 18.			°	°	°			°	°	°
24000	From 1^h 14^m to 2^h 30^m p.m.	Above cloud.	......	......	......	From 2^h 30^m to 2^h 44^m p.m.	Above cloud.	......		
23000			12·4	12·0	+ 0·4			12·5		
22000			13·0	12·2	+ 0·8			12·9		
21000			14·0	12·5	+ 1·5			13·2		
20000			12·0	13·0	− 1·0			13·5		
19000			12·0	13·5	− 1·5			14·0		
18000			12·0	14·2	− 2·2			14·3		
17000			12·0	15·7	− 3·7			14·6		
16000			18·3	17·6	+ 0·7			15·3		
15000			20·0	19·6	+ 0·4			16·6		
14000			21·0	21·7	− 0·7			16·3		
13000			23·0	24·0	− 1·0			17·0		
12000			24·0	26·1	− 2·1			18·0		
11000			31·8	28·2	+ 3·6			20·0		
10000		In cloud or mist.	32·0	30·5	+ 1·5			25·5		
9000			32·1	32·5	− 0·4					
8000			32·5	34·9	− 2·4					
7000			35·6	37·8	− 2·2					
6000			41·0	41·0	0·0					
5000			45·0	45·0	0·0					
4000		Below cloud.	47·9	48·6	− 0·7					
3000			52·3	52·3	0·0					
2000			56·7	55·8	+ 0·9					
1000			59·5	59·5	0·0					
0			••	63·2	......					

April 18.—The sky was cloudy; the amount of deviation of temperature was very small till the height of 7000 feet was reached, when a cold current was met with in the cloud; on passing out of the cloud a warm stratum was passed, and then alternating warm and cold currents were passed, but the amount of deviation was never large. The descent was so rapid that no conclusions can safely be drawn from the observations in these respects.

TABLE III. (*continued.*)

ELEVENTH ASCENT.

Height, in feet, above the mean level of the sea.	Temperature of the Air. Ascending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Descending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
June 26.			°	°	°			°	°	°
23000	From $1^h\ 3^m$ to $1^h\ 55^m$ p.m.	Clouds still above, faint blue sky.	18·5	18·0	+ 0·5	From $1^h\ 55^m$ to $2^h\ 28^m$ p.m.	Clouds above.	18·7	17·8	+ 0·9
22000		In fog.	22·0	18·7	+ 3·3			19·5	18·8	+ 0·7
21000			21·5	19·5	+ 2·0		Fog.	26·0	19·7	+ 6·3
20000		Again in fog, cirri above.	20·3	20·3	0·0		Faint sun.	26·1	21·2	+ 4·9
19000		Just above cloud, faint blue sky; cloud on our lee.	24·0	21·2	+ 2·8			28·9	22·0	+ 6·9
18000		Cold dry thin fog.	33·5	22·5	+11·0			29·1	23·5	+ 5·6
17000			34·5	23·8	+10·7			30·5	24·8	+ 5·7
16000		In fog.	32·0	25·1	+ 6·9			32·0	25·8	+ 6·2
15000		In dry fog.	30·5	26·5	+ 4·0		Rain.	33·0	27·0	+ 6·0
14000			30·8	27·8	+ 3·0			33·0	28·0	+ 5·0
13000		In fog.	30·5	29·1	+ 1·4			33·0	29·2	+ 3·8
12000		Sun seen faintly.	30·5	30·5	0·0		Snow.	33·0	30·4	+ 2·6
11000		In fog.	31·0	31·9	− 0·9			33·0	31·6	+ 1·4
10000		Thin rain.	33·8	33·5	+ 0·3			33·3	32·8	+ 0·5
9000			36·0	35·0	+ 1·0			33·9	33·7	+ 0·2
8000			37·0	37·5	− 0·5		Very murky and thick atmosphere.	34·8	34·8	0·0
7000			40·5	40·0	+ 0·5			36·9	36·6	+ 0·3
6000			43·0	43·0	0·0			38·0	38·2	− 0·2
5000			48·8	47·9	+ 0·9			41·5	41·0	+ 0·5
4000			51·9	51·9	0·0			44·6	44·3	+ 0·3
3000			55·8	55·8	0·0			48·8	48·8	0·0
2000			60·7	60·0	+ 0·7			54·6	54·6	0·0
1000		Very dark.	64·7	63·8	+ 0·9			60·7	60·7	0·0
0			..	68·0	..			66·7	66·7	0·0

June 26.—The morning of this day was very hot and fine; at the time of leaving the earth the sky was cloudy, and there was a continued succession of strata of dry and wet fogs, of warm and cold currents; and rain and snow were both met with; the former at the height of 10,000 feet on ascending, and at 14,000 feet on descending, the snow being situated below the rain on descending, at the height of 13,000 feet.

Between 14,000 feet and 20,000 feet there was a very remarkable warm current, and another, but to a less amount, at 22,000. On descending, whilst passing through rain and snow, or between 10,000 and 17,000 feet, there was scarcely any change of temperature. The results of this day are anomalous.

Table III. (*continued.*)

Twelfth Ascent.

Height, in feet, above the mean level of the sea.	Temperature of the Air. Ascending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Descending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 11.										
4000	From $4^h\,53^m$ to $5^h\,10^m$ p.m.	Thick atmosphere.	61·0	59·1	+ 1·9	From $5^h\,10^m$ to $5^h\,30^m$ p.m.	Thick atmosphere.	63·0	63·0	0·0
3000		Thin mist.	60·7	60·7	0·0			65·3	65·2	+ 0·1
2000			62·9	62·9	0·0			The balloon then turned to ascend.		
1000			69·8	67·5	+ 2·3					
0			..	75·9	..					
6000	From $5^h\,30^m$ to $6^h\,28^m$ p.m.	Very misty	53·5	54·0	− 0·5	From $6^h\,28^m$ to $7^h\,22^m$ p.m.	Very misty.	53·0	51·8	+ 1·2
5000			56·8	57·5	− 0·7			54·0	53·6	+ 0·4
4000		Misty.	60·4	60·4	0·0			56·4	56·4	0·0
3000		Faint sun.	65·0	63·9	+ 1·1			58·8	58·8	0·0
2000			..	..	..			61·3	61·8	− 0·5
1000			..	..	..			64·7	64·7	0·0
								The balloon then turned to ascend.		
2000	From $7^h\,22^m$ to $7^h\,38^m$ p.m.		66·2	65·6	+ 0·6	From $7^h\,38^m$ to $8^h\,0^m$ p.m.		63·3	63·5	− 0·2
1000			66·0	67·5	− 1·5			66·1	66·0	+ 0·1
1000			65·9	65·5	+ 0·4			63·8	64·5	− 0·7
0			..	..	..			68·6	67·9	+ 0·7
Thirteenth Ascent.										
July 21.										
3000	From $4^h\,52^m$ to $5^h\,4^m$ p.m.	Between two layers of cloud.	53·5	53·7	− 0·2	From $5^h\,4^m$ to $5^h\,13^m$ p.m.	Cloud higher.	53·5	53·6	− 0·1
2000		Dense fog.	56·1	56·4	− 0·3		In cloud.	55·3	55·1	+ 0·2
1000		In cloud.	60·0	59·4	+ 0·6			58·0	57·7	+ 0·3
0			61·4	62·5	− 1·1					
3000	From $5^h\,13^m$ to $5^h\,19^m$ p.m.	Fog.	54·2	53·7	+ 0·5	From $5^h\,19^m$ to $5^h\,28^m$ p.m.	Wetting fog.	52·1	52·5	− 0·4
2000		In cloud.	54·0	54·9	− 0·9		In black cloud.	55·5	55·1	+ 0·4
1000		Fog.	58·0	58·0	0·0		Rain.	59·6	59·6	0·0
1000	From $5^h\,28^m$ to $5^h\,33^m$ p.m.	Rain; very dark.	60·0	60·0	0·0	From $5^h\,33^m$ to $5^h\,45^m$ p.m.	Very dark, and rain.	60·0	60·0	0·0
0			..	..	..			61·5	61·8	− 0·3

July 11.—The sky was nearly covered with cloud, and the amount of deviation from the adopted temperatures was always small.

July 21.—Heavy rain was falling on the earth during the ascent. The temperature declined almost evenly, and there is no great departure from the adopted curve.

The next Table has been formed by taking the difference between consecutive numbers in the preceding Tables in each ascent.

TABLE IV.—Showing the decrease of Temperature

Height above the level of the sea.		March 31.		April 18.	June 26.		July 11.							July 21.	
		State of the Sky.													
		Misty below 3000 ft.	Clear.	Cloudy below 9000 ft.	Cloudy.		Cloudy.							Cloudy.	
From	To	Ascending.	Descending.	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Descending.	Ascending.	Descending.
ft.	ft.	°	°	°	°	°	°	°	°	°	°	°	°	°	°
28000	29000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27000	28000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26000	27000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25000	26000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24000	25000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23000	24000	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22000	23000	1·0	...	...	0·7	1·0	...	...	...	...	...	...	...	...	...
21000	22000	1·2	0·8	0·3	0·8	0·9	...	...	...	...	...	...	...	...	...
20000	21000	1·8	0·7	0·5	0·8	1·5	...	...	...	...	...	...	...	...	...
19000	20000	1·9	0·4	0·5	0·9	0·8	...	...	...	...	...	...	...	...	...
18000	19000	2·1	0·8	0·7	1·3	1·5	...	...	...	...	...	...	...	...	...
17000	18000	1·9	1·0	1·5	1·3	1·3	...	...	...	...	...	...	...	...	...
16000	17000	2·1	1·5	1·9	1·3	1·0	...	...	...	...	...	...	...	...	...
15000	16000	2·0	1·7	2·0	1·4	1·2	...	...	...	...	...	...	...	...	...
14000	15000	2·0	2·2	2·1	1·3	1·0	...	...	...	...	...	...	...	...	...
13000	14000	2·0	2·0	2·3	1·3	1·2	...	...	...	...	...	...	...	...	...
12000	13000	2·3	2·1	2·1	1·4	1·2	...	...	...	...	...	...	...	...	...
11000	12000	2·6	2·0	2·1	1·4	1·2	...	...	...	...	...	...	...	...	...
10000	11000	2·7	1·9	2·3	1·6	1·2	...	...	...	...	...	...	...	...	...
9000	10000	2·3	1·6	2·0	1·5	0·9	...	...	...	...	...	...	...	...	...
8000	9000	2·2	2·0	2·4	2·5	1·1	...	...	...	...	...	...	...	...	...
7000	8000	2·2	1·8	2·9	2·5	1·8	...	...	...	...	...	...	...	...	...
6000	7000	2·2	1·7	3·2	3·0	1·6	...	...	...	...	...	...	...	...	...
5000	6000	2·2	1·5	3·0	4·9	2·8	...	...	3·5	1·8	...	...	...	...	...
4000	5000	2·3	1·7	4·6	4·0	3·3	...	...	2·9	2·8	...	...	...	...	..
3000	4000	2·0	1·8	3·7	3·9	4·5	1·6	2·2	3·5	2·4	...	...	...	...	..
2000	3000	3·0	2·0	3·5	4·2	5·8	2·2	...	...	3·0	...	...	...	2·7	1·
1000	2000	3·0	3·3	3·7	3·8	6·1	4·6	...	...	2·9	1·9	2·5	...	3·0	2·
0	1000	4·9	7·2	3·7	4·2	6·0	8·4	...	...	...	...	...	3·4	3·1	..
No. of Col.		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.

The numbers at the lower elevations are all larger than those at the higher, agreeing in this respect with the results of the experiments of the preceding year, and those with a clear sky are larger than those with a cloudy sky, also agreeing with preceding results.

The numbers in columns 18 and 20 show the mean results from the experiments of this year, the former when the sky was cloudy, and the latter when clear or mostly clear. The numbers in column 19 show the number of experiments upon which each result in column 18 is based; at heights exceeding 5000 feet the experiments were mostly made on one day, viz. June 26, the only day, in fact, on which clouds have reached and enveloped the balloon in different strata and densities, exceeding the height of 4 miles. The numbers in column 21 show the number of experiments with clear skies, and they are but few. The numbers in column 22 show the total number of experiments which have been made at the different heights with a cloudy sky from the be-

in every 1000 feet of elevation up to 29,000 feet.

July 21.			Mean.				General Means (omitting July 17, 1862).					
State of the Sky.												
Cloudy.							Cloudy.			Clear.		
Ascending.	Descending.	Descending.	Cloudy.	Number of experiments.	Clear.	Number of experiments.	Mean.	Number of experiments.	Space passed for a decline of 1°.	Mean.	Number of experiments.	Space passed for a decline of 1°.
°	°	°	°		°		°		feet.	°		feet.
...	...	...	...	...	...	...	...	...	...	0·8	1	1250
...	...	...	...	...	...	...	...	...	...	0·9	1	1111
...	...	...	...	...	...	...	...	...	...	1·0	1	1000
...	...	...	...	...	...	...	...	...	...	1·0	1	1000
...	...	...	...	...	...	...	...	...	...	1·1	2	911
...	...	...	...	...	...	...	...	...	...	1·3	2	771
...	...	...	0·8	2	...	....	0·8	2	1250	1·0	4	1000
...	...	...	0·8	2	0·8	3	0·8	2	1250	1·1	7	911
...	...	...	1·1	2	1·0	3	1·1	2	911	1·2	7	833
...	...	...	0·9	2	0·9	3	0·9	2	909	1·3	7	771
...	...	...	1·4	2	1·2	3	1·4	2	715	1·5	7	666
...	...	...	1·3	2	1·5	3	1·3	2	771	1·7	7	588
...	...	...	1·2	2	1·8	3	1·2	2	833	1·9	7	526
...	...	...	1·3	2	1·9	3	1·3	2	771	2·0	7	500
...	...	...	1·2	2	2·1	3	1·2	2	833	2·1	7	477
...	...	...	1·2	2	2·1	3	1·2	2	833	2·2	9	455
...	...	...	1·3	2	2·2	3	1·3	2	771	2·4	9	417
...	...	...	1·3	2	2·2	3	1·3	2	771	2·5	9	400
...	...	...	1·4	2	2·3	3	1·4	2	715	2·5	11	400
...	...	...	1·5	3	2·0	3	1·5	2	667	2·5	10	400
...	...	...	2·0	3	2·1	2	2·0	2	500	2·5	10	400
...	...	...	2·4	3	2·0	2	2·4	2	417	2·5	10	400
...	...	...	2·6	3	2·0	2	2·6	3	385	2·6	10	385
...	...	...	3·2	5	1·9	2	3·2	5	313	2·6	12	385
...	...	...	3·5	5	2·0	2	3·3	11	303	2·7	7	374
...	...	...	3·0	8	1·8	1	3·4	18	294	3·2	8	312
1·2	2·6	...	3·0	10	2·0	1	3·6	20	278	4·0	7	250
3·1	4·5	...	3·4	12	3·3	1	3·8	19	264	5·0	6	200
...	...	1·8	4·4	8	7·2	1	4·5	15	222	7·2	6	139
15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.

ginning of the experiments, and these vary from 11 to 20 up to 5000 feet, and the results must therefore be very nearly true.

The numbers in column 26 show the total number of experiments which have been made at the different heights with clear or nearly clear skies; they vary from 4 to 12 up to the height of 23,000 feet, and there can be but little doubt that the numbers in column 25 are closely approximate to the true numbers up to this elevation; above 24,000 feet, the number of experiments are too few to speak with any confidence.

The numbers in column 22, showing the decrease of temperature for 1000 feet increase of elevation with a cloudy sky, differ very much from those in column 25, showing the decrease for the same space with a clear sky, the former being much smaller up to the height of 18,000 feet; at heights greater than 19,000 feet the differences between the results in the two states of the sky are small.

The numbers in column 24 show the average increase of elevation at every

1000 feet, for a decrease of temperature of 1° with a cloudy sky; from these we see that up to 1000 feet the average space is 222 feet, the space for each 1000 feet increasing till at 20,000 feet it requires fully 1000 feet for a change of 1° of temperature.

In the last column the same results are shown for clear, or nearly clear sky, and they show that a change of 1° takes place for an average increase of 139 feet in the first 1000 feet; this space gradually increasing to fully 1000 feet at heights exceeding 23,000 feet.

By comparing the numbers in columns 24 and 27 together, the different spaces required to be passed through for a decline of 1° of temperature in the two states of the sky will be readily seen: up to 20,000 feet it is generally necessary to pass through a much larger change of elevation for a decline of 1° of temperature than with a clear sky; at heights exceeding 20,000 feet, there does not seem to be much difference in this respect between the two states of the sky.

Cloudy Sky.

By adding together successively the numbers in column 22, we shall find the whole decrease of temperature from the earth to the different elevations; the results with a cloudy sky are as follows:—

	feet		°		feet.
From 0 to	1,000	the decrease was	4·5,	or 1° on the average of	222
,,	2,000	,,	8·3	,,	241
,,	3,000	,,	11·9	,,	253
,,	4,000	,,	15·3	,,	262
,,	5,000	,,	18·6	,,	269
,,	6,000	,,	21·8	,,	275
,,	7,000	,,	24·4	,,	287
,,	8,000	,,	26·8	,,	299
,,	9,000	,,	28·8	,,	313
,,	10,000	,,	30·3	,,	331
,,	11,000	,,	31·7	,,	348
,,	12,000	,,	33·0	,,	365
,,	13,000	,,	34·3	,,	381
,,	14,000	,,	35·5	,,	395
,,	15,000	,,	36·7	,,	409
,,	16,000	,,	38·0	,,	422
,,	17,000	,,	39·2	,,	434
,,	18,000	,,	40·5	,,	445
,,	19,000	,,	41·9	,,	455
,,	20,000	,,	42·8	,,	468
,,	21,000	,,	43·9	,,	479
,,	22,000	,,	44·7	,,	492
,,	23,000	,,	45·5	,,	506

These results, showing the whole decrease of temperature of the air from the earth up to 23,000 feet, differ very considerably from those with a clear sky, to be spoken of presently. The numbers in the last column show the average increment of height for a decline of 1°, as found by using the temperatures of the extremities of the column alone. To 1000 feet high the average is 1° in 222 feet, increasing gradually to 1° in 300 feet at 8000 feet high, and to 506 feet at the height of 23,000 feet.

Clear Sky.

By adding together the numbers in column 25 in the same way the following results are found:—

	feet					feet.
From 0 to	1,000	the decrease was	7·2	or 1° on the average of		139
,,	2,000	,,	12·2	,,		164
,,	3,000	,,	16·2	,,		186
,,	4,000	,,	19·4	,,		207
,,	5,000	,,	22·1	,,		227
,,	6,000	,,	24·7	,,		243
,,	7,000	,,	27·3	,,		257
,,	8,000	,,	29·8	,,		269
,,	9,000	,,	32·3	,,		278
,,	10,000	,,	34·8	,,		288
,,	11,000	,,	37·3	,,		295
,,	12,000	,,	39·8	,,		302
,,	13,000	,,	42·2	,,		308
,,	14,000	,,	44·4	,,		316
,,	15,000	,,	46·5	,,		323
,,	16,000	,,	48·5	,,		331
,,	17,000	,,	50·4	,,		338
,,	18,000	,,	52·1	,,		346
,,	19,000	,,	53·6	,,		356
,,	20,000	,,	54·9	,,		365
,,	21,000	,,	56·1	,,		375
,,	22,000	,,	57·2	,,		385
,,	23,000	,,	58·0	,,		396
,,	24,000	,,	59·3	,,		406
,,	25,000	,,	60·4	,,		416
,,	26,000	,,	61·4	,,		425
,,	27,000	,,	62·4	,,		434
,,	28,000	,,	63·3	,,		444
,,	29,000	,,	64·1	,,		454
,,	30,000	,,	64·6	,,		464

These results, showing the whole decrease of temperature from the ground to 30,000 feet, differ greatly, as just mentioned, from those with a cloudy sky.

The numbers in the last column, showing the average increase of height for a decline of 1° of temperature from the ground to that elevation, are all smaller than those with a cloudy sky at the same elevation. Each result, up to 22,000 feet, is based upon at least six experiments, taken at different times of the year, and up to this height considerable confidence may be placed in the results; they show that a change takes place in the first 1000 feet of 1° on an average of every 139 feet, increasing to about 300 feet at 11,000 or 12,000 feet; in the experiments taken in the year 1862, this space of 300 feet was at 14,000 feet high, therefore the changes of temperature have been less in 1863 than those in 1862. The latter experiments, however, have been taken at different times of the year from those of the former, and it would seem probable that this element varies with the season of the year. Every experiment proves that the theory of a decline of 1° for every increase of 300 feet must be absolutely put on one side, as without exception the fall of 1° has always taken place in the smallest space when near the earth. To determine this space, and also the law of decrease near the earth, all the observations of temperature of the air up to 5000 feet were laid down on large diagrams, and a line was made to pass through them, giving equal weight to every observation; the result at every 200 feet was then read out, and in this way the next series of Tables were formed.

Table V.—Showing the Mean Temperature of the Air at every 200 feet up to 5000 feet.—Ninth Ascent.

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
March 31.			°	°	°			°	°	°
5000	From 4h 10m p.m. to 4h 24m p.m.	Blue sky.	36·0	36·7	− 0·7	From 6h 14m p.m. to 6h 38m p.m.	Cloudless.	25·9	26·0	− 0·1
4800			37·0	37·2	− 0·2			26·5	26·4	+ 0·1
4600			37·3	37·6	− 0·3			27·4	26·7	+ 0·7
4400			37·5	38·1	− 0·6			28·0	27·0	+ 1·0
4200			37·6	38·5	− 0·9			28·0	27·4	+ 0·6
4000			38·2	38·9	− 0·7			28·0	27·7	+ 0·3
3800			38·5	39·3	− 0·8			28·1	28·0	+ 0·1
3600			38·0	39·7	− 1·7			28·2	28·4	− 0·2
3400			38·0	40·1	− 2·1			28·4	28·7	− 0·3
3200			38·8	40·5	− 1·7			28·5	29·1	− 0·6
3000			39·6	41·0	− 1·4			29·2	29·5	− 0·3
2800		Misty.	40·5	41·6	− 1·1			29·7	29·7	0·0
2600			41·3	42·2	− 0·9			30·0	30·0	0·0
2400			42·2	42·8	− 0·6			30·0	30·5	− 0·5
2200			43·0	43·4	− 0·4			30·0	31·0	− 1·0
2000			44·0	44·0	0·0			30·0	31·5	− 1·5
1800			44·8	44·5	+ 0·2			30·5	32·0	− 1·5
1600			45·7	45·1	+ 0·6			31·4	32·6	− 1·2
1400			46·3	45·7	+ 0·6			32·0	33·2	− 1·2
1200			46·8	46·4	+ 0·4			32·4	33·9	− 1·5
1000			47·2	47·0	+ 0·2			33·5	34·8	− 1·3
800			47·5	47·6	+ 0·1			36·0	36·0	0·0
600			48·4	48·5	+ 0·1			37·5	37·5	0·0
400			..	49·6	..			39·0	39·0	0·0
200			..	50·7	..			40·5	40·5	0·0
0			..	51·9	..			42·0	42·0	0·0
Tenth Ascent.										
April 18.										
5000	From 1h 14m p.m. to 1h 22m p.m.	In cloud or mist.	45·0	45·0	0·0					
4800			45·9	45·8	+ 0·1					
4600			46·6	46·5	+ 0·1					
4400			47·3	47·2	+ 0·1					
4200			47·6	47·9	− 0·3					
4000		Below cloud.	47·9	48·6	− 0·7					
3800			48·5	49·4	− 0·9					
3600			49·0	50·1	− 1·1					
3400			49·8	50·8	− 1·0					
3200			51·0	51·6	− 0·6					
3000			52·3	52·3	0·0					
2800			52·8	53·0	− 0·2					
2600			54·4	53·7	+ 0·7					
2400			55·2	54·4	+ 0·8					
2200			56·3	55·1	+ 1·2					
2000			56·7	55·8	+ 0·9					
1800			56·9	56·5	+ 0·4					
1600			57·3	57·3	0·0					
1400			58·0	58·0	0·0					
1200			58·8	58·8	0·0					
1000			59·5	59·5	0·0					
800			..	60·1						
600			..	60·9						
400			..	61·6						
200			..	62·4						
0			..	63·2						

Table V. (*continued.*)

Eleventh Ascent.

Height, in feet, above the mean level of the sea.	Temperature of the Air. Ascending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Descending. Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
June 26.			°	°	°			°	°	°
5000	From 1^h 3^m p.m. to 1^h 9^m p.m.	..	48·1	47·9	+ 0·2	From 2^h 23^m p.m. to 2^h 28^m p.m.	Very misty and thick.	41·5	41·0	+ 0·5
4800		..	48·8	48·7	+ 0·1			42·0	41·5	+ 0·5
4600		..	49·5	49·5	0·0			42·5	42·2	+ 0·3
4400		..	50·3	50·3	0·0			43·2	42·8	+ 0·4
4200		..	51·1	51·1	0·0			44·0	43·5	+ 0·5
4000		..	51·9	51·9	0·0			44·6	44·3	+ 0·3
3800		..	52·7	52·7	0·0			45·4	45·7	+ 0·3
3600		..	53·5	53·5	0·0			46·0	45·8	+ 0·2
3400		..	54·2	54·2	0·0			46·8	46·7	+ 0·1
3200		..	55·0	55·0	0·0			47·5	47·7	− 0·2
3000		..	55·8	55·8	0·0			48·8	48·8	0·0
2800		..	56·6	56·6	0·0			49·9	49·9	0·0
2600		..	57·6	57·5	+ 0·1			51·0	51·0	0·0
2400		..	58·6	58·4	+ 0·2			52·2	52·2	0·0
2200		..	59·7	59·2	+ 0·5			53·4	53·4	0·0
2000		Very dark.	60·7	60·0	+ 0·7			54·6	54·6	0·0
1800			61·7	60·9	+ 0·8			55·9	55·9	0·0
1600			62·5	61·7	+ 0·8			57·1	57·1	0·0
1400			62·7	62·4	+ 0·3			58·3	58·3	0·0
1200			63·6	63·1	+ 0·5			59·5	59·5	0·0
1000			64·7	63·8	+ 0·9			60·7	60·7	0·0
800			..	64·6	..			61·8	61·8	0·0
600			..	65·4	..			63·1	63·1	0·0
400			..	66·2	..			64·3	64·3	0·0
200			..	67·1	..			65·5	65·5	0·0
0			..	68·0	..			66·7	66·7	0·0
Twelfth Ascent.										
July 11.										
4600	From 4^h 53^m p.m. to 5^h 7^m p.m.	Atmosphere thick and misty.	60·0	59·8	+ 0·2	From 5^h 7^m p.m. to 5^h 34^m p.m.	Atmosphere thick and misty.	60·0	61·8	− 1·8
4400			58·7	59·0	− 0·3			61·5	62·1	− 0·6
4200			59·7	59·0	+ 0·7			62·0	62·5	− 0·5
4000			61·0	59·1	+ 1·9			63·0	63·0	0·0
3800		Thin mist.	57·9	59·3	− 1·4			64·0	63·5	+ 0·5
3600			59·1	59·6	− 0·5			64·9	64·0	+ 0·9
3400			59·8	60·0	− 0·2			65·2	64·4	+ 0·8
3200			60·3	60·3	0·0			65·7	64·8	+ 0·9
3000			60·7	60·7	0·0			65·3	65·2	+ 0·1
2800			61·0	61·0	0·0		Sun seen faintly.	65·0	65·6	− 0·6
2600			61·4	61·4	0·0			65·0	66·0	− 1·0
2400			61·8	61·8	0·0			65·7	66·5	− 0·8
2200			62·3	62·3	0·0			The balloon then turned to ascend.		
2000			62·9	62·9	0·0					
1800			63·8	63·8	0·0					
1600			64·7	64·7	0·0					
1400			65·5	65·5	0·0					
1200			66·4	66·4	0·0					
1000			69·8	67·5	+ 2·3					
800			69·0	68·8	+ 0·2					
600			70·4	70·4	0·0					
400			72·2	72·2	0·0					
200			74·0	74·0	0·0					
0			..	75·9						

Table V. (*continued.*)

Twelfth Ascent (*continued*).

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed-temp.	Adopted temp.	Calculated effect of disturbance.
July 11.			°	°	°			°	°	°
5000	From 5^h 34^m p.m. to 6^h 13^m p.m.	Very misty.	56·8	57·5	−0·7	From 7^h 1^m 30^s p.m. to 7^h 22^m p.m.	Very misty.	54·0	53·6	+0·4
4800			57·7	57·8	−0·1			54·2	54·0	+0·2
4600		Misty.	58·6	58·3	+0·3			54·6	54·6	0·0
4400			59·0	59·0	0·0		...	55·2	55·2	0·0
4200			59·7	59·7	0·0		...	55·8	55·8	0·0
4000			60·4	60·4	0·0		...	56·4	56·4	0·0
3800			60·6	61·1	−0·5		...	57·0	57·0	0·0
3600			62·0	61·8	+0·2		...	57·6	57·6	0·0
3400		Sun seen faintly.	63·9	62·5	+1·4		...	58·0	58·0	0·0
3200			64·5	63·2	+1·3		...	58·3	58·3	0·0
3000			65·0	63·9	+1·1		...	58·8	58·8	0·0
2800			65·1	64·6	+0·5		...	59·5	59·5	0·0
2600			65·5	65·4	+0·1		...	60·1	60·1	0·0
2400			65·1	66·2	−1·1		...	60·7	60·7	0·0
2200		...	...	...	...		...	61·0	60·3	+0·7
2000		...	...	...	...		...	61·3	61·8	−0·5
1800		...	...	...	...		...	62·3	62·3	0·0
1600		...	...	...	...		...	62·9	62·9	0·0
1400		...	...	...	...		...	63·5	63·5	0·0
1200		...	...	...	...		...	64·1	64·1	0·0
1000		...	...	...	...		...	64·7	64·7	0·0
								The balloon then turned to ascend.		
2600	From 7^h 26^m 30^s p.m. to 7^h 37^m 30^s p.m.	...	64·4	64·8	−0·4	From 7^h 37^m 30^s p.m. to 7^h 59^m 45^s p.m.	...	63·0	63·0	0·0
2400		...	65·5	65·0	+0·5		...	63·0	63·0	0·0
2200		...	66·0	65·3	+0·7		...	63·0	63·2	−0·2
2000		...	66·2	65·6	+0·6		...	63·3	63·5	−0·2
1800		...	66·7	65·9	+0·8		...	63·7	63·8	−0·1
1600		...	66·8	66·3	+0·5		...	64·1	64·1	0·0
1400		...	66·5	66·7	−0·2		...	64·5	64·5	0·0
1200		...	66·9	67·1	−0·2		...	65·5	65·5	0·0
1000		...	66·0	67·5	−1·5		...	66·1	66·0	+0·1
800		...	...	...	...		...	...	...	...
								The balloon then turned to ascend.		
1600	From 7^h 59^m 45^s p.m. to 8^h 25^m 30^s p.m.	...	64·5	64·5	0·0	From 8^h 25^m 30^s p.m. to 8^h 50^m p.m.	...	64·2	63·8	+0·4
1400		...	64·7	64·7	0·0		...	64·3	64·0	+0·3
1200		...	65·0	65·0	0·0		...	64·3	64·2	+0·1
1000		...	65·9	65·5	+0·4		...	63·8	64·5	−0·7
800		...	65·1	66·0	−0·9		...	64·8	64·9	−0·1
600		...	...	...	...		...	65·3	65·4	−0·1
400		...	...	...	...		...	66·2	66·0	+0·2
200		...	...	...	...		...	67·5	66·8	+0·7
0		...	...	...	...		...	68·6	67·9	+0·7

Table V. (*continued.*)

Thirteenth Ascent.

Height, in feet, above the mean level of the sea.	Temperature of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.	Between what times.	Circumstances.	Observed temp.	Adopted temp.	Calculated effect of disturbance.
July 21.			°	°	°			°	°	°
3000	From 4^h 52^m p.m. to 5^h 3^m p.m.	Out of cloud.	53·5	53·7	−0·2	From 5^h 3^m p.m. to 5^h 11^m p.m.	In open space.	53·5	53·6	−0·1
2800		In dense fog.	54·0	54·0	0·0			53·5	53·6	−0·1
2600			54·0	54·4	−0·4			53·5	53·8	−0·3
2400		In dry cloud.	54·7	55·1	−0·4			54·0	54·2	−0·2
2200			55·6	55·7	−0·1			54·5	54·6	−0·1
2000			56·1	56·3	−0·2		In cloud.	55·3	55·1	+0·2
1800			56·6	57·0	−0·4			55·7	55·6	+0·1
1600		In cloud, clouds very light.	57·8	57·6	+0·2			56·0	56·0	0·0
1400			58·2	58·3	−0·1			56·1	56·5	−0·4
1200			59·2	59·0	+0·2			56·8	57·0	−0·2
1000		Entered clouds.	60·0	59·5	+0·5			58·0	57·7	+0·3
800			60·3	60·1	+0·2			The balloon then turned to ascend.		
600			60·5	60·6	−0·1					
400			60·8	61·2	−0·4					
200			61·0	61·6	−0·6					
0		Sky overcast.	61·4	62·1	−0·7					
3400	From 5^h 11^m to 5^h 20^m 30^s p.m.		53·1	...	...	From 5^h 20^m 30^s to 5^h 32^m p.m.				
3200		Fog.	53·0	53·5	−0·5		Wetting fog.	52·4	52·2	+0·2
3000			54·2	53·7	+0·5			52·1	52·5	−0·4
2800			55·0	54·0	+1·0			52·3	52·8	−0·5
2600			54·2	54·2	0·0			53·0	53·3	−0·3
2400			54·2	54·4	−0·2			53·8	53·8	0·0
2200			54·1	54·6	−0·5		Black cloud.	54·9	54·4	+0·5
2000		Cloud.	54·0	54·9	−0·9			55·5	55·1	+0·4
1800			54·9	55·4	−0·5			56·0	55·9	+0·1
1600			56·0	56·0	0·0			56·6	56·6	0·0
1400		Fog.	57·0	56·5	+0·5			57·2	57·4	−0·2
1200			57·5	57·1	+0·4		Rain.	58·1	58·5	−0·4
1000			58·0	58·0	0·0			59·6	59·6	0·0
800			...	...	...			61·8	61·8	0·0
600			...	...	...			61·5	63·0	−1·5
								The balloon then turned to ascend.		
1800	From 5^h 32^m p.m. to 5^h 35^m p.m.		57·2	57·2	0·0	From 5^h 35^m p.m. to 5^h 45^m p.m.		58·1	58·1	0·0
1600			57·5	57·5	0·0			59·0	58·5	+0·5
1400			58·2	58·2	0·0			58·7	58·9	−0·2
1200		Rain. Very dark.	59·0	59·0	0·0		Very dark cloud.	59·4	59·4	0·0
1000			60·0	59·9	+0·1			60·0	60·0	0·0
800			61·0	60·8	+0·2			61·5	60·6	+0·9
600			61·5	61·8	−0·3			61·5	61·1	+0·4
400			...	...	...			61·5	61·6	−0·1
200			...	...	...		Rain.	61·5	62·1	−0·6
0			...	..	...			61·5	62·7	−1·2

TABLE VI.—Showing the Decrease of Temperature with every

Height above the level of the sea.		March 31.		April 18.	June 26.		July 11.									
		State of the Sky.														
		Misty.	Clear.	Cloudy.	Cloudy.		Misty.									
From	To	Ascending.	Descending.	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.
feet.	feet.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
4900	5000	0·2	0·2	0·4	0·4	0·3	..	..	0·1	0·2	..	..	..	..	..	..
4800	4900	0·3	0·2	0·4	0·4	0·3	..	..	0·2	0·2	..	..	..	..	..	..
4700	4800	0·2	0·1	0·4	0·4	0·3	..	..	0·2	0·3	..	..	..	..	..	..
4600	4700	0·2	0·2	0·4	0·4	0·3	..	..	0·3	0·3	..	..	..	..	..	..
4500	4600	0·2	0·1	0·4	0·4	0·3	..	0·1	0·3	0·3	..	..	..	..	..	..
4400	4500	0·3	0·2	0·4	0·4	0·3	..	0·2	0·4	0·3	..	..	..	..	..	..
4300	4400	0·2	0·2	0·4	0·4	0·3	..	0·2	0·3	0·3	..	..	..	..	..	..
4200	4300	0·2	0·2	0·4	0·4	0·4	..	0·2	0·4	0·3	..	..	..	..	..	..
4100	4200	0·2	0·1	0·4	0·4	0·4	..	0·2	0·3	0·3	..	..	..	..	..	..
4000	4100	0·2	0·2	0·4	0·4	0·4	0·1	0·3	0·4	0·3	..	..	..	..	..	..
3900	4000	0·2	0·1	0·4	0·4	0·4	0·1	0·2	0·3	0·3	..	..	..	..	..	..
3800	3900	0·2	0·2	0·4	0·4	0·4	0·1	0·3	0·4	0·3	..	..	..	..	..	..
3700	3800	0·2	0·2	0·4	0·4	0·3	0·1	0·2	0·3	0·3	..	..	..	..	..	..
3600	3700	0·2	0·2	0·4	0·4	0·4	0·2	0·3	0·4	0·3	..	..	..	..	..	..
3500	3600	0·2	0·1	0·4	0·3	0·4	0·2	0·2	0·3	0·3	..	..	..	..	..	..
3400	3500	0·2	0·2	0·3	0·4	0·5	0·2	0·2	0·4	0·3	..	..	..	..	..	..
3300	3400	0·2	0·2	0·4	0·4	0·5	0·1	0·2	0·3	0·3	..	..	..	..	..	..
3200	3300	0·2	0·2	0·4	0·4	0·5	0·2	0·2	0·4	0·3	..	..	..	..	..	..
3100	3200	0·2	0·2	0·4	0·4	0·5	0·2	0·2	0·3	0·3	..	..	..	..	..	..
3000	3100	0·3	0·2	0·4	0·4	0·6	0·2	0·2	0·4	0·4	..	..	..	..	..	..
2900	3000	0·3	0·1	0·4	0·4	0·5	0·1	0·2	0·3	0·3	..	..	..	..	0·2	..
2800	2900	0·3	0·1	0·4	0·4	0·6	0·2	0·2	0·4	0·3	..	..	..	..	0·3	..
2700	2800	0·3	0·1	0·4	0·4	0·5	0·2	0·2	0·4	0·3	..	..	..	..	0·3	0·1
2600	2700	0·3	0·2	0·5	0·5	0·6	0·2	0·2	0·4	0·3	..	..	..	..	0·3	0·1
2500	2600	0·3	0·2	0·4	0·4	0·6	0·2	0·2	0·4	0·3	0·1	..	..	..	0·3	0·2
2400	2500	0·3	0·3	0·5	0·5	0·6	0·2	0·3	0·4	0·3	0·1	..	..	..	0·3	0·2
2300	2400	0·3	0·2	0·4	0·4	0·6	0·2	..	..	0·2	0·1	0·1	..	..	0·2	0·2
2200	2300	0·3	0·3	0·4	0·4	0·6	0·3	..	..	0·3	0·2	0·1	..	..	0·3	0·2
2100	2200	0·3	0·2	0·4	0·4	0·6	0·3	..	..	0·2	0·1	0·1	..	..	0·2	0·2
2000	2100	0·3	0·3	0·4	0·4	0·6	0·3	..	..	0·3	0·2	0·2	..	..	0·3	0·3
1900	2000	0·3	0·2	0·4	0·4	0·6	0·4	..	..	0·3	0·1	0·1	..	..	0·3	0·2
1800	1900	0·2	0·3	0·5	0·5	0·7	0·5	..	..	0·3	0·2	0·2	..	..	0·3	0·3
1700	1800	0·3	0·3	0·4	0·4	0·6	0·4	..	..	0·3	0·2	0·1	..	..	0·3	0·2
1600	1700	0·3	0·3	0·4	0·4	0·6	0·5	..	..	0·3	0·2	0·2	..	..	0·3	0·2
1500	1600	0·3	0·3	0·4	0·3	0·6	0·4	..	..	0·3	0·2	0·2	0·1	0·1	0·3	0·2
1400	1500	0·3	0·3	0·3	0·4	0·6	0·4	..	..	0·3	0·2	0·2	0·1	0·1	0·4	0·3
1300	1400	0·3	0·3	0·3	0·3	0·6	0·4	..	..	0·3	0·2	0·2	0·1	0·1	0·3	0·2
1200	1300	0·4	0·4	0·4	0·4	0·6	0·5	..	..	0·3	0·2	0·3	0·2	0·1	0·3	0·3
1100	1200	0·3	0·4	0·3	0·3	0·6	0·5	..	..	0·3	0·2	0·2	0·2	0·1	0·3	0·3
1000	1100	0·3	0·5	0·4	0·4	0·6	0·6	..	..	0·3	0·2	0·3	0·3	0·2	0·3	0·4
900	1000	0·3	0·6	0·4	0·4	0·5	0·6	..	..	..	..	0·2	0·2	0·2	0·3	..
800	900	0·3	0·6	0·4	0·4	0·6	0·7	..	..	..	..	0·3	0·3	0·2	0·3	..
700	800	0·4	0·7	0·4	0·4	0·6	0·8	..	..	..	..	..	..	0·2	0·3	..
600	700	0·5	0·8	0·4	0·4	0·7	0·8	..	..	..	..	..	..	0·3	0·3	..
500	600	0·5	0·7	0·4	0·4	0·6	0·8	..	..	..	..	..	..	0·3	0·3	..
400	500	0·6	0·8	0·4	0·4	0·6	0·9	..	..	..	..	..	..	0·3	0·3	..
300	400	0·5	0·7	0·4	0·4	0·6	0·9	..	..	..	..	..	..	0·4	0·3	..
200	300	0·6	0·8	0·4	0·4	0·6	1·0	..	..	..	..	..	..	0·4	0·3	..
100	200	0·6	0·7	0·4	0·4	0·6	0·9	..	..	..	..	..	..	0·5	0·3	..
0	100	0·6	0·8	0·5	0·5	0·6	1·0	..	..	..	..	..	..	0·6	0·4	..
No. of column		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.

Increase of Height of 100 feet up to 5000 feet.

July 21.				Mean.									
State of the Sky.													
Overcast.								Cloudy.			Clear.		
Ascending.	Descending.	Ascending.	Descending.	Cloudy.	Number of experiments.	Clear.	Number of experiments.	Mean.	Number of experiments.	Space passed through for a decline of 1°.	Mean.	Number of experiments.	Space passed through for a decline of 1°.
°	°	°	°	°		°		°		feet.	°		feet.
..	..	..	..	0·3	5	0·2	2	0·3	15	334	0·3	5	334
..	..	..	..	0·3	5	0·2	2	0·3	15	334	0·3	5	334
..	..	..	..	0·3	5	0·2	2	0·3	14	334	0·3	5	334
..	..	..	..	0·3	5	0·2	2	0·3	14	334	0·3	5	334
..	..	..	..	0·3	5	0·2	2	0·3	15	334	0·3	5	334
..	..	..	..	0·3	6	0·2	2	0·3	15	334	0·3	5	334
..	..	..	..	0·3	6	0·2	2	0·3	18	334	0·3	5	334
..	..	..	..	0·3	6	0·2	2	0·3	18	334	0·3	5	334
..	..	..	..	0·3	6	0·2	2	0·3	18	334	0·3	7	334
..	..	..	..	0·3	7	0·2	2	0·3	19	334	0·3	7	334
..	..	..	..	0·3	7	0·2	2	0·3	19	334	0·3	7	334
..	..	..	..	0·3	7	0·2	2	0·3	19	334	0·3	7	334
..	..	..	..	0·3	8	0·2	1	0·3	20	334	0·3	6	334
..	..	..	..	0·3	8	0·2	1	0·3	20	334	0·3	6	334
..	..	..	..	0·3	8	0·1	1	0·3	20	334	0·3	6	334
..	..	..	..	0·3	8	0·2	1	0·3	20	334	0·3	6	334
..	..	..	..	0·3	8	0·2	1	0·3	20	334	0·3	6	334
..	..	..	..	0·3	8	0·2	1	0·3	20	334	0·3	6	334
0·1	0·1	..	..	0·3	10	0·2	1	0·3	22	334	0·3	6	334
0·1	0·2	..	..	0·3	10	0·2	1	0·4	21	251	0·3	6	334
0·1	0·1	..	..	0·3	10	0·1	1	0·4	22	251	0·3	6	334
0·2	0·2	..	..	0·3	11	0·1	1	0·4	22	251	0·3	6	334
0·1	0·2	..	..	0·3	12	0·1	1	0·4	23	251	0·3	6	334
0·1	0·3	..	..	0·3	12	0·2	1	0·4	23	251	0·3	6	334
0·1	0·2	..	..	0·3	13	0·2	1	0·4	24	251	0·3	6	334
0·1	0·3	..	..	0·3	13	0·3	1	0·4	24	251	0·3	6	334
0·1	0·3	..	..	0·3	12	0·2	1	0·4	23	251	0·3	6	334
0·1	0·3	..	..	0·3	12	0·3	1	0·4	23	251	0·3	6	334
0·1	0·3	..	..	0·3	12	0·2	1	0·4	23	251	0·3	6	334
0·2	0·4	..	..	0·3	12	0·3	1	0·4	23	251	0·3	6	334
0·2	0·4	..	..	0·3	12	0·2	1	0·4	23	251	0·3	6	334
0·3	0·4	..	..	0·3	12	0·3	1	0·4	23	251	0·3	6	334
0·3	0·3	0·1	0·2	0·3	14	0·3	1	0·4	25	251	0·3	6	334
0·3	0·4	0·2	0·2	0·3	14	0·3	1	0·4	25	251	0·3	6	334
0·2	0·4	0·3	0·2	0·3	16	0·3	1	0·4	27	251	0·4	7	251
0·3	0·4	0·4	0·2	0·3	16	0·3	1	0·4	27	251	0·4	7	251
0·3	0·5	0·4	0·2	0·3	16	0·3	1	0·4	25	251	0·4	5	251
0·3	0·6	0·4	0·3	0·3	16	0·4	1	0·4	25	251	0·5	5	201
0·4	0·5	0·4	0·3	0·3	16	0·4	1	0·4	25	251	0·5	5	201
0·5	0·6	0·5	0·3	0·4	16	0·5	1	0·4	25	251	0·5	5	201
..	0·6	0·4	0·3	0·4	12	0·6	1	0·4	21	251	0·5	5	201
..	0·6	0·5	0·3	0·4	12	0·6	1	0·4	19	251	0·6	5	167
..	0·6	0·5	0·2	0·4	10	0·7	1	0·4	19	251	0·6	5	167
..	0·6	0·5	0·3	0·5	10	0·8	1	0·4	19	251	0·6	5	167
..	..	...	0·2	0·5	8	0·7	1	0·5	17	201	0·6	5	167
..	..	..	0·3	0·5	8	0·8	1	0·5	17	201	0·6	5	167
..	..	..	0·2	0·5	8	0·7	1	0·5	17	201	0·6	5	167
..	..	..	0·3	0·5	8	0·8	1	0·5	17	201	0·7	5	143
..	..	..	0·3	0·5	8	0·7	1	0·5	17	201	0·7	5	143
..	..	..	0·3	0·6	8	0·8	1	0·6	17	167	0·8	5	125
16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.

The largest numbers are those at the bottom of the column, and the smallest at the top, or at the highest elevations. The numbers in column 20 show the mean with the cloudy skies, and those in 22 the results with clear or partially clear skies, but there was only one such instance in the year 1863. The numbers in column 24 show the general mean from all the experiments with cloudy skies, as based upon experiments varying in number from 14 to 27; and in column 26 the space in feet for a decline of 1° is shown, being 167 feet near the earth, increasing gradually to 334 feet at heights exceeding 3000 feet. In column 29 the results for clear or partially clear skies are shown, being 125 feet for 1° near the earth, increasing gradually to 334 feet at 1700 feet, above which it is nearly constant up to 5000 feet.

From these results we may conclude that in a cloudy state of the sky the decline of temperature is less in amount and more nearly uniform up to the clouds, than in a clear sky, and that the greatest change in both states of the sky is near the earth.

§ 6. Variation of the Hygrometric condition of the Air with Elevation.

All the adopted readings of the temperature of the dew-point in Section 4 were laid down on diagrams, and their points joined. As it was evident then to the eye that the changes did not follow a regular decrease in the temperature of the air, the numbers at every 1000 feet were read from the diagram, and in this way the next Tables were formed.

Table VII.—Showing the Variation of the Hygrometric condition of the Air at every 1000 feet of Height.

Ninth Ascent.

Height, in feet, above the mean level of the sea.	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
March 31.	From 4h 10m p.m. to 5h 27m p.m.					From 5h 27m p.m. to 6h 30m p.m.	Cloudless.			
23000			Unknown, but certainly less than −40°.	Unknown, but certainly less than ·006.	Unknown, but certainly less than 7.			Unknown, but certainly less than −40°.	Unknown, but certainly less than ·006.	Unknown, but certainly less than 7.
22000										
21000										
20000										
19000										
18000										
17000			°	in.				°	in.	
16000			...	...	...			−29·0	·010	19
15000			...	...	...			−26·0	·012	24
14000			...	...	...			−23·0	·014	24
13000			...	...	...			−19·0	·017	23
12000		Clear blue sky.	−36·0	·007	7			−16·0	·020	25
11000			−26·0	·012	10			−14·5	·022	25
10000			−16·5	·020	14			−13·8	·022	23
9000			− 4·0	·036	23			−12·5	·024	23
8000			5·5	·055	32			−12·0	·024	21
7000			9·5	·066	35			− 9·5	·028	23
6000			12·0	·074	35			0·0	·044	33
5000			20·0	·108	53			3·0	·050	36
4000			22·0	·118	51			8·0	·062	45
3000		Misty.	28·0	·153	62			15·0	·086	53
2000			28·5	·156	54			19·8	·108	61
1000			34·0	·196	60			21·0	·113	61
420			38·2	·231	67					

March 31.—At the earth's surface the dew-point was 38°; it decreased to $28\frac{1}{2}°$ at 2000 feet, and continued almost at this value to 3500 feet; at 4000 feet it fell suddenly to 22°, and again suddenly at 5000 feet; after this it declined much more rapidly than the temperature of the air; and the air at 10,000 feet high became very dry, and exceedingly so at heights exceeding 15,000 feet.

On descending, the temperature of the dew-point was very much below that of the air to the height of 6000 feet, and afterwards it approached that of the air rather quickly.

In ascending, the air was moist while passing through mist between 1000 and 3000 feet high, and the degree of humidity varied from 54 to 62; another moist stratum was situated between 4000 and 5000 feet; above this the amount of water diminished very quickly, the degree of humidity at 12,000 feet being 7 only, and at points higher than this it was much less. On descending, the declining curve was interrupted at 4500 feet, at 3000 feet, and at 1500 feet by narrow bands of different degrees of humidity.

TABLE VII. (*continued.*)

TENTH ASCENT.

Height, in feet, above the mean level of the sea.	Humidity of the Air. Ascending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
April 18.			°	in.	
17000	From 1^h 14^m p.m. to 2^h 30^m p.m.	Above cloud.	−20·0	·017	23
16000			−16·0	·020	23
15000			−12·0	·024	22
14000			− 7·0	·031	28
13000			− 2·0	·040	33
12000			2·0	·048	37
11000			6·0	·057	32
10000		In cloud or mist.	10·5	·069	38
9000			17·0	·094	52
8000			25·0	·135	73
7000			32·0	·181	87
6000			33·8	·194	76
5000			34·0	·196	67
4000		Below cloud.	35·0	·204	61
3000			40·0	·247	64
2000			45·5	·305	68
1000			49·0	·348	69
420			50·2	·364	68

April 18.—The temperature of the dew-point was 50° on the ground, the air was misty; at 1000 feet high, and again at 2200 feet, moist strata of air were passed, the difference between the temperatures of the air and dew-point becoming less in both cases; these two temperatures then separated till the height of 4000 feet was reached, when the air again became more moist, and at 7000 feet high the temperature of the air was only 2° above that of the dew-point; at this time the mist almost amounted to a fog. The degree of humidity was 87; on passing above this, the temperature of the dew-point rapidly and almost evenly declined, and at heights exceeding 17,000 feet the air became very dry.

Table VII. (*continued.*)—Eleventh Ascent.

Height, in feet, above the mean level of the sea.	Humidity of the Air. Ascending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Descending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
June 26.			°	in.				°	in.	
23000	From 1^h 3^m p.m. to 1^h 55^m p.m.	Clouds still above; faint blue sky.	− 2·0	·040	40	From 1^h 55^m p.m. to 2^h 28^m p.m.	Clouds above.	9·5		
22000		In fog.	− 2·3	·040	34			2·0		
21000			−18·5	·018	18		Fog.	− 4·5	·036	26
20000		In fog; cirri above.	−15·5	·021	19			5·0	·054	38
19000			−17·5	·019	15		Faint sun.	3·0	·050	32
18000		Just above cloud; faint blue sky; clouds on our level.	9·0	·065	34			3·0	·050	32
17000		Cold dry thin fog.	18·0	·098	49			10·5	·069	46
16000		In fog.	20·5	·110	68		Rain.	15·5	·088	49
15000		In dry fog.	24·5	·132	78			14·5	·084	45
14000			31·0	·174	100		Snow.	22·0	·118	63
13000		In fog.	30·5	·170	100			24·0	·129	69
12000		Sun seen faintly.	28·0	·153	91			23·0	·123	65
11000		In fog; thin rai	22·0	·118	68			20·0	·108	58
10000			16·0	·090	46			12·0	·074	59
9000			11·0	·071	35		Very murky and thick atmosphere.	15·0	·086	44
8000			10·5	·069	57			15·5	·088	44
7000			15·0	·086	34			18·5	·100	43
6000			24·5	·132	48			22·5	·120	54
5000			34·0	·196	69			26·0	·141	53
4000			41·0	·257	67			34·0	·196	68
3000			45·0	·299	68			39·5	·242	72
2000			45·0	·299	57			43·5	·283	68
1000		Very dark.	48·0	·335	55			48·0	·335	65
300			50·0	·361	56			...	...	...
0			...	...	...			55·0	·433	66

June 26.—The temperature of the dew-point was 50°, and on leaving the earth it declined less rapidly than the temperature, so that the humidity increased; after passing above 4000 feet the dew-point declined rather quickly to 6000 feet, where its rapid decline was checked, but continued to decline to 8000 feet; it was here as low as $10\frac{1}{2}$°; it was 11° at 9000 feet, and then increased, momentarily approaching that of the air; and at 12,700 feet, having passed through rain at 10,000 feet, these two temperatures were alike, and the air was saturated with moisture, and continued thus to 14,200 feet high; it then separated, and whilst passing through a dry fog at 15,000 feet, whilst the air was increasing in temperature, the dew-point decreased; on passing out of cloud at 18,000 feet the air became dry, and from 20,000 feet to 23,000 feet the dew-point was from 30° to 40° below that of air; at this time rain-clouds were at the same height, and at 23,000 feet the air again was so moist, that the difference between these two temperatures was 6° only. The degree

of humidity varied very much, from 100 at 13,000 and 14,000 feet to 19 at 20,000 feet and to 40 at 23,000 feet.

On descending, the temperature of the dew-point separated from that of the air, and was 30° less at 21,000 feet; on passing then into fog, the moisture increased so rapidly that at 19,800 feet there was only 6° difference between these temperatures; it again separated, and again approached whilst passing through rain and snow; on passing below the snow at 10,000 feet, the air at first became drier, but afterwards the increase of the temperature of the dew-point was more rapid than that of the air, and the air became more humid. Both the temperature of the air and the distribution of the water in this ascent were very remarkable.

Table VII. (*continued.*)—Twelfth Ascent.

Height, in feet, above the mean level of the sea.	Humidity of the Air.									
	Ascending.					Descending.				
	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
July 11.			°	in.				°	in.	
4600	From $4^h 53^m$ p.m. to $5^h 7^m$ p.m.	Atmosphere thick and misty.	50·3	·365	75	From $5^h 7^m$ p.m. to $5^h 34^m$ p.m.	Atmosphere thick and misty.	50·3	·365	75
4400			49·8	·358	72			49·5	·355	65
4200			48·0	·335	65			49·2	·351	63
4000			47·8	·333	62			47·0	·323	56
3800		Thin mist.	44·6	·295	62			49·2	·351	59
3600			43·3	·280	56			50·0	·361	59
3400			43·5	·283	65			51·0	·374	62
3200			43·5	·283	54			51·0	·374	59
3000			43·4	·281	53		Sun seen faintly.	50·9	·373	60
2800			43·2	·279	52			50·7	·370	60
2600			43·5	·283	52			50·5	·367	60
2400			43·2	·279	55			50·2	·364	69
2200			43·0	·277	49			The balloon then turned to ascend.		
2000			43·0	·277	48					
1800			46·0	·311	52					
1600			50·0	·361	60					
1400			50·2	·364	59					
1200			48·5	·342	54					
1000			47·0	·323	44					
800			47·5	·329	47					
600			48·6	·343	46					
400			50·0	·361	46					
200			51·1	·375	45					
0			52·2	·391	44					

July 11.—The balloon first rose to 4600 feet, the degree of humidity increasing with elevation; it then descended to 2600 feet, and the temperature of the dew-point was nearly constant. The balloon then turned to ascend, and reached a height of 6600 feet; the humidity increased as before to 5400 feet, and then became somewhat less humid; on descending, the air at first increased in humidity, and then decreased, being driest at the lowest part of the descent, viz. 1000 feet. The balloon then turned to ascend for a third time and reached 2600 feet, with a somewhat drier atmosphere than had been met with at this elevation on this day; at this time the track of the balloon was near the sea; on descending to 800 feet the air was more humid; and this was found to be the case by ascending for the fourth time to 1600 feet, and again confirmed on finally descending to the height of 800 feet, when the instruments were packed up.

Table VII. (*continued.*)

Twelfth Ascent (*continued*).

Height, in feet, above the mean level of the sea.	Humidity of the Air. Ascending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Descending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
July 11.			°	in.				°	in.	
6600	From $5^h\ 34^m$ p.m. to $6^h\ 28^m$ p.m.	Misty.	40·0	·247	68	From $6^h\ 28^m$ p.m. to $7^h\ 25^m\ 30^s$ p.m.	Very misty.	41·0	·257	64
6400		Cirrus & cirro-stratus clouds far above.	41·3	·260	63			41·8	·265	70
6200			42·5	·272	63		...	41·3	·260	65
6000			43·1	·278	68		...	42·2	·269	67
5800			46·3	·315	70		...	41·7	·264	72
5600			48·0	·335	73		...	42·0	·267	69
5400			50·4	·394	85		...	43·0	·277	70
5200		Very misty.	49·0	·348	75		...	44·2	·288	70
5000			49·4	·353	76		...	45·7	·307	73
4800			48·5	·342	72		...	47·0	·323	77
4600		Misty.	49·2	·351	71		...	48·0	·335	78
4400			46·7	·319	65		...	47·2	·325	75
4200			46·5	·317	61		...	46·6	·318	71
4000			47·0	·323	62		...	46·0	·311	68
3800			47·9	·334	63		...	45·5	·305	65
3600		Faint sun.	49·7	·357	64		...	45·0	·299	63
3400			49·8	·358	63		...	44·0	·288	60
3200			49·6	·356	59		...	43·2	·279	57
3000			49·0	·348	56		...	42·5	·272	55
2800			50·5	·367	59		...	42·3	·270	64
2600			49·0	·348	55		...	42·6	·273	53
2400			49·6	·356	58		...	42·8	·275	53
2200			...	...	...		...	43·0	·277	52
2000		...	...	...	...		...	43·0	·277	51
1800		...	...	...	...		...	43·1	·278	51
1600		...	...	...	...		...	44·1	·289	50
1400		...	...	...	...		...	46·0	·311	52
1200		...	...	...	...		...	47·0	·323	53
1000		...	...	...	...		...	47·7	·331	53
0								The balloon then turned to ascend.		
2600	From $7^h\ 25^m\ 30^s$ p.m. to $7^h\ 37^m\ 30^s$ p.m.	...	44·5	·294	49	From $7^h\ 37^m\ 30^s$ p.m. to 8^h p.m.	...	45·2	·302	52
2400		...	42·0	·267	43		...	47·0	·323	56
2200		...	40·9	·256	41		...	45·6	·306	53
2000		...	41·8	·265	41		...	44·5	·294	55
1800		...	43·3	·280	43		...	44·5	·294	50
1600		...	43·5	·283	43		...	46·3	·315	53
1400		...	43·8	·286	49		...	48·0	·335	55
1200		...	45·8	·308	46		...	49·3	·352	57
1000		...	48·6	·343	45		...	50·9	·373	59
800		...	...	...	...		...	51·1	·375	60
								The balloon then turned to ascend.		
1600	From $8^h\ 1^m$ p.m. to $8^h\ 11^m\ 30^s$ p.m.	...	49·0	·348	58	From $8^h\ 11^m\ 30^s$ p.m. to $8^h\ 20^m$ p.m.	...	48·6	·343	57
1400		...	49·0	·348	57		...	49·5	·355	59
1200		...	50·2	·364	59		...	50·0	·361	60
1000		...	50·0	·361	55		...	50·6	·369	62
800		...	50·7	·370	60		...	51·0	·374	61

TABLE VII. (*continued.*)

THIRTEENTH ASCENT.

Height, in feet, above the mean level of the sea.	Humidity of the Air. Ascending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.	Descending. Between what times.	Circumstances.	Temperature of the dew-point.	Elastic force of vapour.	Degree of humidity.
July 21.			°	in.				°	in.	
3000	From $4^h\ 52^m$ p.m. to $5^h\ 3^m$ p.m.	Out of cloud.	52·5	·396	97	From $5^h\ 3^m$ p.m. to $5^h\ 11^m$ p.m.		52·5	·396	97
2800		In dense fog.	54·0	·418	100		In open space.	51·0	·374	91
2600			54·0	·418	100			53·0	·403	98
2400		In dry cloud.	54·7	·428	100			53·0	·403	96
2200			55·6	·443	100		In cloud	53·0	·403	95
2000		In clouds; clouds very light.	55·4	·439	97			53·3	·407	93
1800			54·6	·427	93			52·5	·396	89
1600			55·2	·436	91			54·0	·418	93
1400			56·2	·453	93			55·1	·434	96
1200		Entered clouds.	57·0	·465	93			56·0	·449	97
1000			57·0	·465	90			The balloon then turned to ascend.		
800			57·4	·472	91					
600			58·0	·482	91					
400		Sky overcast.	59·0	·500	94					
200			60·2	·522	94					
0			60·5	·528	96					
3200	From $5^h\ 11^m$ p.m. to $5^h\ 20^m\ 30^s$ p.m		52·8	·400	99	From $5^h\ 20^m\ 30^s$ p.m. to $5^h\ 32^m$ p.m.		51·0	·374	85
3000		Fog.	52·7	·399	95		Wetting fog.	52·1	·389	100
2800			53·0	·403	93			52·2	·391	99
2600			53·0	·403	96			52·5	·396	98
2400			53·6	·412	100			52·9	·401	97
2200			53·9	·416	99		Black cloud.	53·5	·410	95
2000		Cloud.	54·0	·418	100			53·0	·403	91
1800			54·9	·431	100			53·2	·406	94
1600			56·0	·449	100			54·5	·425	93
1400			57·0	·465	100			56·0	·449	96
1200		Fog.	57·5	·473	100			57·6	·475	98
1000			58·0	·482	100		Rain.	59·5	·509	99
800			...	...	...			61·8	·552	100
600			...	...	...			61·5	·546	100
								The balloon then turned to ascend.		
1800	From $5^h\ 32^m$ p.m. to $5^h\ 35^m\ 45^s$ p.m.		57·0	·465	99	From $5^h\ 35^m\ 45^s$ p.m. to $5^h\ 37^m\ 45^s$ p.m.		58·1	·483	100
1600			57·5	·473	100		Very dark cloud.	59·0	·500	100
1400			58·2	·485	100			58·6	·492	100
1200		Rain; very dark.	59·0	·500	100			59·4	·507	100
1000			60·0	·518	100		Rain.	60·0	·518	100
800			61·0	·537	100					
600			61·5	·546	100					

July 21.—Rain was falling heavily on leaving the earth; the degree of humidity at first decreased, and then increased and decreased again, till on passing into dense fog at 2200 feet the air was saturated. On descending to 1400 feet the air was nearly saturated; on rising a second time the air was again saturated, and was nearly so up to 3200 feet; on the second descent the humidity varied from 91 to 100, and afterwards the air was quite saturated from 1800 feet to the earth. Rain had been falling heavily all the time the balloon was in the air.

TABLE VIII.—Showing the Degree of Humidity at every 1000 feet up to 24,000 feet.

Height above the level of the sea.	March 31.		April 18.	June 26.		July 11.								July 21.						Mean.			
	State of the Sky.																						
	Misty below 3000 ft.	Clear.	Cloudy below 9000 ft.	Cloudy.		Cloudy.								Cloudy.									
	Descending.	Ascending.	Ascending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Ascending.	Descending.	Cloudy.	Number of experiments.	Clear.	Number of experiments.
feet.																							
24000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23000	...	...	...	40	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	40	1	...	...
22000	...	...	...	34	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	34	1	...	...
21000	...	...	...	18	26	...	...	...	...	...	...	...	...	...	...	...	...	...	...	22	2	...	...
20000	...	...	...	19	38	...	...	...	...	...	...	...	...	...	...	...	...	...	...	29	2	...	...
19000	...	...	...	15	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	24	2	...	...
18000	...	...	...	34	32	...	...	...	...	...	...	...	...	...	...	...	...	...	...	33	2	...	...
17000	...	...	23	49	46	...	...	...	...	...	...	...	...	...	...	...	...	...	...	47	2	23	1
16000	...	19	23	68	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...	59	2	21	2
15000	...	24	22	78	45	...	...	...	...	...	...	...	...	...	...	...	...	...	...	62	2	23	2
14000	...	24	28	100	63	...	...	...	...	...	...	...	...	...	...	...	...	...	...	81	2	26	2
13000	...	23	33	100	69	...	...	...	...	...	...	...	...	...	...	...	...	...	...	84	2	28	2
12000	7	25	37	91	65	...	...	...	...	...	...	...	...	...	...	...	...	...	...	78	2	23	3
11000	10	25	32	68	58	...	...	...	...	...	...	...	...	...	...	...	...	...	...	63	2	22	3
10000	14	23	38	46	59	...	...	...	...	...	...	...	...	...	...	...	...	...	...	53	2	25	3
9000	23	23	52	35	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	44	3	23	2
8000	32	21	73	57	44	...	...	...	...	...	...	...	...	...	...	...	...	...	...	58	3	27	2
7000	35	23	87	34	43	...	...	...	...	...	...	...	...	...	...	...	...	...	...	55	3	29	2
6000	35	33	76	48	54	...	...	68	67	...	...	...	...	...	...	...	...	...	...	63	5	34	2
5000	53	36	67	69	53	...	...	76	73	...	...	...	...	...	...	...	...	...	...	67	5	44	2
4000	51	45	61	67	68	62	56	62	68	...	...	...	...	...	...	...	...	...	...	63	7	48	2
3000	62	53	64	68	72	53	60	56	55	...	...	...	...	97	97	95	100	...	...	73	12	53	1
2000	54	61	68	57	68	48	...	...	51	41	55	...	...	97	93	100	91	...	...	69	12	61	1
1000	60	61	69	55	65	44	...	...	53	55	59	55	62	90	...	100	99	100	100	71	15	61	1
0	67	...	69	56	66	44	...	...	...	...	...	...	...	96	...	...	...	...	97	71	7	...	...

The numbers in this Table show, as in the previous experiments, that the moisture in the air at the same elevation is very different at different times; the numbers in the last column of the Table show the average results in the two states of clear and cloudy skies, with the number of experiments upon which each result is based. By combining those with cloudy sky with those previously obtained, according to the number of observations upon which each result was based, the following results were obtained.

With an overcast sky, the degree of humidity on the earth was	74	from	12	experiments.
At 1000 feet	73	,,	23	,,
2000 ,,	73	,,	23	,,
3000 ,,	76	,,	24	,,
4000 ,,	73	,,	17	,,
5000 ,,	75	,,	10	,,
6000 ,,	70	,,	8	,,
7000 ,,	58	,,	5	,,
8000 ,,	54	,,	5	,,
9000 ,,	46	,,	5	,,
10,000 ,,	51	,,	4	,,
11,000 ,,	53	,,	4	,,
12,000 ,,	55	,,	4	,,
13,000 ,,	53	,,	4	,,
14,000 ,,	48	,,	4	,,
15,000 ,,	62	,,	2	,,
16,000 ,,	59	,,	2	,,
17,000 ,,	47	,,	2	,,
18,000 ,,	33	,,	2	,,
19,000 ,,	24	,,	2	,,
20,000 ,,	29	,,	2	,,
21,000 ,,	22	,,	2	,,
22,000 ,,	34	,,	1	,,
23,000 ,,	40	,,	1	,,

The law of moisture here indicated is an almost uniform state of humidity to the height of 5000 or 6000 feet, that is, to the usual height of the cloud plane; then a sudden decrease and continued decrease to 14,000 feet. At elevations exceeding 14,000 feet with cloudy skies the number of experiments are too few to speak with confidence of the results; the humidity, however, seems generally to decrease; the high numbers at 15,000 and 16,000 feet are probably accidental.

By treating the results with a clear or a nearly clear sky in the same way, the following results were obtained.

With a clear sky, the degree of humidity was

On the ground	63	from 4	experiments.
At 1000 feet	67	„ 6	„
2000 „	70	„ 6	„
3000 „	72	„ 6	„
4000 „	70	„ 9	„
5000 „	63	„ 8	„
6000 „	59	„ 8	„
7000 „	56	„ 9	„
8000 „	51	„ 9	„
9000 „	45	„ 7	„
10,000 „	42	„ 8	„
11,000 „	41	„ 8	„
12,000 „	35	„ 6	„
13,000 „	40	„ 5	„
14,000 „	36	„ 5	„
15,000 „	44	„ 5	„
16,000 „	40	„ 5	„
17,000 „	39	„ 4	„
18,000 „	21	„ 2	„
19,000 „	36	„ 2	„
20,000 „	33	„ 1	„
21,000 „	32	„ 1	„
22,000 „	21	„ 1	„
23,000 „	16	„ 1	„

The law of moisture here shown is a steady increase of humidity from the ground to the height of 3000 or 4000 feet, then a decrease by 5000 feet to the same as on the ground, declining afterwards, but not regularly, to the height of 23,000 feet; above this point the air is very dry, but, so far as I have seen, never quite free from water.

By comparing the results with a cloudy sky with those from a clear sky, the degree of humidity on the ground with the latter is less by 11 than with the former, but approximate very closely together at the height of 3000 feet; the air continues humid with the cloudy sky to 5000 or 6000 feet, but becomes less humid with a clear sky at 4000 feet, and declines, but less rapidly than with cloudy sky, till at 7000 feet they are again near together, and continue so to 9000 feet; the humidity then increases with the cloudy sky to the height of 15,000 feet, where the air is as humid as at the height of 7000 feet; whilst with the clear sky the humidity decreases to the height of 13,000 feet, but then increases to 15,000 feet, where the air is as humid as it was at 10,000 feet. It is remarkable that this humid state is in both states of the sky at the same elevation; at elevations greater than this, the humidity decreases in both states of the sky, but more rapidly at first with the cloudy than with the clear state, till at heights exceeding 20,000 feet there is but little difference in the results from the two states.

§ 7. Comparison of the Temperature of the Dew-point, as determined by different Instruments.

Table IX.—Showing the Temperature of the Dew-point, as determined at about the same height by different instruments and methods, and comparison of the results together.

Under 1000 feet.

Date.	Height.	Dew-point temperatures. Calculated from: Dry and Wet (free).	Dew-point temperatures. Calculated from: Dry and Wet (aspirated).	Dew-point temperatures. Observed by: Daniell's Hygrometer.	Dew-point temperatures. Observed by: Regnault's Hygrometer.	Temperature of the dew-point as determined by Dry and Wet (free) above that by: Dry and Wet (aspirated).	Temperature of the dew-point as determined by Dry and Wet (free) above that by: Daniell's Hygrometer.	Temperature of the dew-point as determined by Dry and Wet (free) above that by: Regnault's Hygrometer.
d h m	feet.	°	°	°	°	°	°	°
March 31 4 7	350	38·3	..	38·0	..	..	+ 0·3	
4 11	350	38·3	..	..	36·2	..	..	+ 2·1
June 26 1 6¼	....	45·9	..	..	48·9	..	..	− 3·0
July 11 4 44	....	52·7	..	55·0	..	..	− 2·3	
4 45	....	52·8	..	53·5	..	..	− 0·7	
4 47	....	52·2	..	55·0	..	..	− 2·8	
4 51	....	51·4	..	54·0	..	..	− 2·6	
8 1	760	50·9	..	51·0	..	..	− 0·1	
21	....	59·0	..	..	59·5	..	..	− 0·5
5 29½	948	61·1	..	..	61·5	..	..	− 0·4

Between 1000 and 2000 feet.

Date.	Height.	Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.
March 31 4 18	1515	29·2	..	..	30·0	..	..	− 0·8
July 11 7 13½	1876	42·4	..	44·0	..	..	− 1·6	
7 15	1876	43·0	..	43·5	..	..	− 0·5	
7 16½	1776	42·7	..	43·0	..	..	− 0·3	
7 19	1582	44·4	..	44·5	..	..	− 0·1	
7 20	1485	45·2	..	45·2	..	..	0·0	
7 22	1290	46·4	..	45·5	..	..	+ 0·9	
7 26½	1029	48·0	..	48·5	..	..	− 0·5	
7 27¼	1119	46·6	..	48·0	..	..	− 1·4	
7 28¾	1341	44·4	..	45·0	..	..	− 0·6	
7 30	1231	45·1	..	44·5	..	..	+ 0·6	
7 32	1096	45·5	..	45·0	..	..	+ 0·5	
7 33	1488	43·0	..	42·5	..	..	+ 0·5	
7 46	1580	45·8	..	47·0	..	..	− 1·2	
7 47	1483	47·0	..	47·5	..	..	− 0·5	
7 49	1483	49·4	..	48·0	..	..	+ 1·4	
7 50	1337	49·2	..	48·5	..	..	+ 0·7	
7 52½	1145	49·0	..	49·0	..	..	0·0	
7 55	1000	50·0	..	50·0	..	..	0·0	
7 56¾	1020	50·7	..	50·5	..	..	+ 0·2	
7 57¼	1029	49·9	..	50·8	..	..	− 0·9	
8 4	1290	50·0	..	51·5	..	..	− 1·5	
21 5 15½	1241	57·5	..	58·0	..	..	− 0·5	

TABLE IX. (*continued.*)

Between 2000 and 3000 feet.

Date.				Height.	Dew-point temperatures.				Temperatures of the dew-point as determined by		
					Calculated from		Observed by		Dry and Wet (free) above that by		
					Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.
	d	h	m	feet.	°	°	°	°	°	°	
June	26	1	7	2651	45·7	..	47·0	..	..	− 1·3	
July	11	5	34	2470	50·3	..	50·8	..	..	− 0·5	
		5	37	2469	49·9	..	50·5	..	..	− 0·6	
		5	40	2424	47·9	..	52·0	..	..	− 4·1	
		5	42	2470	47·0	..	50·5	..	..	− 3·5	
		5	43½	2488	48·3	..	50·9	..	..	− 2·6	
		5	45	2488	48·5	..	49·5	..	..	− 1·0	
		5	48	2817	50·4	..	50·0	..	..	+ 0·4	
		5	49	2820	50·9	..	50·0	..	..	+ 0·9	
		5	50	2820	51·6	..	50·5	..	..	+ 1·1	
		5	52	2707	51·6	..	51·0	..	..	+ 0·6	
		5	53	2926	49·0	..	50·0	..	..	− 1·0	
		7	12	2199	44·0	..	44·5	..	..	− 0·5	
		7	35	2426	41·8	..	42·0	..	..	− 0·2	
		7	36	2555	42·2	..	42·5	..	..	− 0·3	
		7	38	2657	44·6	..	43·5	..	..	+ 1·1	
		7	38½	2597	44·6	..	44·0	..	..	+ 0·6	
July	21	4	58	2790	54·2	..	54·5	..	..	− 0·3	
		5	1	2610	55·0	..	55·0	..	..	0·0	
		5	2	2850	54·2	..	54·0	..	..	+ 0·2	
		5	3	2900	53·1	..	53·0	..	..	+ 0·1	
		5	5	2890	50·7	..	52·0	..	..	− 1·3	
		5	23½	2870	52·2	..	52·0	..	..	+ 0·2	

Between 3000 and 4000 feet.

Date.				Height.	Dry and Wet (free).	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.	Dry and Wet (aspirated).	Daniell's Hygrometer.	Regnault's Hygrometer.
July	11	5	4	3930	45·8	..	46·0	..	..	− 0·2	
		5	14	3860	47·9	..	49·0	..	..	− 1·1	
		5	15	....	47·9	..	50·2	..	..	− 2·3	
		5	24	3524	50·4	..	50·0	..	..	+ 0·4	
		5	29½	....	50·4	..	51·5	..	..	− 1·1	
		5	53½	3046	49·0	..	50·0	..	..	− 1·0	
		5	56	3529	49·8	..	50·0	..	..	− 0·2	
		6	1	....	50·2	..	50·0	..	..	+ 0·2	
		6	3	3250	50·3	..	50·0	..	..	+ 0·3	
		6	4	3250	49·8	..	51·0	..	..	− 1·2	
		6	5½	3720	48·1	..	50·3	..	..	− 2·2	
		7	6½	3855	45·5	..	46·4	..	..	− 0·9	
		7	8	3277	42·9	..	46·0	..	..	− 3·1	
		7	9½	3068	42·5	..	45·5	..	..	− 3·0	
	21	5	20½	3298	51·8	..	51·5	..	..	+ 0·3	

TABLE IX. (*continued.*)

Between 4000 and 5000 feet.

Date.	Height.	Dew-point temperatures. Calculated from Dry and Wet (free).	Dew-point temperatures. Calculated from Dry and Wet (aspirated).	Dew-point temperatures. Observed by Daniell's Hygrometer.	Dew-point temperatures. Observed by Regnault's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by Dry and Wet (aspirated).	Temperatures of the dew-point as determined by Dry and Wet (free) above that by Daniell's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by Regnault's Hygrometer.
d h m	feet.	°	°	°	°	°	°	
July 11 5 5½	4030	46·8	..	46·5	..	..	+ 0·3	
5 7	4366	49·7	..	51·5	..	..	− 1·8	
5 7½	4610	50·3	..	48·5	..	..	+ 1·8	
5 16	4171	49·0	..	49·2	..	..	− 0·2	
6 9	4610	47·0	..	49·0	..	..	− 2·0	
6 12	4905	49·5	..	49·2	..	..	+ 0·3	
7 3	4706	47·4	..	47·3	..	..	+ 0·1	
7 4	4380	47·2	..	46·7	..	..	+ 0·5	

Between 5000 and 6000 feet.

March 31 6 11½	5901	0·0	..	0·0	..	..	0·0	
July 11 6 13	5105	49·5	..	50·0	..	..	− 0·5	
6 14	5271	47·8	..	49·0	..	..	− 1·2	
6 15	5327	48·6	..	49·0	..	..	− 0·4	
6 16	5382	51·2	..	49·5	..	..	+ 1·7	
6 18	5684	47·2	..	48·0	..	..	− 0·8	
6 20	5772	46·6	..	47·1	..	..	− 0·5	
6 21	5828	46·4	..	47·0	..	..	− 0·6	
6 22	5884	45·5	..	46·5	..	..	− 1·0	
6 58	5975	41·6	..	41·0	..	..	+ 0·6	
6 59	5523	42·0	..	41·5	..	..	+ 0·5	
7 1½	5150	44·4	..	48·0	..	..	− 3·6	

Between 6000 and 7000 feet.

July 11 6 24	6451	40·9	..	42·5	..	..	− 1·6	
6 27	6623	38·6	..	42·0	..	..	− 3·4	
6 32	6186	41·2	..	41·5	..	..	− 0·3	
6 34	6186	41·0	..	41·5	..	..	− 0·5	
6 35	6210	41·0	..	40·8	..	..	+ 0·2	
6 47	6031	43·4	..	42·0	..	..	+ 1·4	
6 47½	....	42·5	..	41·8	..	..	+ 0·7	
6 48	6309	43·0	..	41·5	..	..	+ 1·5	
6 50	6420	42·4	..	41·5	..	..	+ 0·9	
6 52	6453	39·6	..	40·4	..	..	− 0·8	
6 53	6475	40·7	..	40·0	..	..	+ 0·7	
6 54½	6530	41·7	..	40·5	..	..	+ 1·2	
6 55	6588	41·7	..	40·5	..	..	+ 1·2	
6 55½	6588	41·7	..	41·5	..	..	+ 0·2	
6 56	6530	40·5	..	40·0	..	..	+ 0·5	

TABLE IX. (*continued.*)

Between 7000 and 8000 feet.

Date.	Height.	Dew-point temperatures: Calculated from: Dry and Wet (free).	Dew-point temperatures: Calculated from: Dry and Wet (aspirated).	Dew-point temperatures: Observed by: Daniell's Hygrometer.	Dew-point temperatures: Observed by: Regnault's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Dry and Wet (aspirated).	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Daniell's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Regnault's Hygrometer.
d h m	feet.	°	°	°	°	°	°	°
March 31 4 27½	7035	9·3						
6 8	7907	11·8	..	10·0	..	..	+ 1·8	

Between 8000 and 9000 feet.

June 26 1 15	....	..	..	11·0				

Between 10,000 and 11,000 feet.

March 31 4 35	10047	−16·9						

Between 14,000 and 15,000 feet.

March 31 5 56	14325	− 4·6	..	−10·0	..	..	+ 5·4	
June 26 1 23	14530	22·1	..	20·0	..	..	+ 2·1	

Between 15,000 and 16,000 feet.

March 31 5 52	15630	−28·1						
June 26 1 26	15935	15·2	..	..	17·2	..	− 2·0	

Between 16,000 and 17,000 feet.

March 31 5 46	16080	− 7·4						
June 26 1 27	16079	13·4	..	17·0	..	..	− 3·6	
1 29⅓	....	19·5	..	..	21·0	..	..	− 1·5
1 29¾	....	22·0	..	..	24·2	..	..	− 2·2
1 30	....	21·5	..	..	23·5	..	..	− 2·0

Between 18,000 and 19,000 feet.

June 26 1 35½	18053	3·3	..	9·0				
1 36¾	18555	− 5·0	..	..	− 9·2	..	..	+ 4·2
1 37	....	−14·1	..	..	− 5·0	..	..	− 9·1
1 38	....	−17·4	..	− 4·8	− 4·2	..	..	−13·2

TABLE IX. (*continued.*)

Between 19,000 and 20,000 feet.

Date.	Height.	Dew-point temperatures: Calculated from: Dry and Wet (free).	Dew-point temperatures: Calculated from: Dry and Wet (aspirated).	Dew-point temperatures: Observed by: Daniell's Hygrometer.	Dew-point temperatures: Observed by: Regnault's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Dry and Wet (aspirated).	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Daniell's Hygrometer.	Temperatures of the dew-point as determined by Dry and Wet (free) above that by: Regnault's Hygrometer.
d h m	feet.	°	°	°	°	°	°	°
June 26 1 41·10	19544	−12·5	..	..	− 9·5	..	..	− 3·0
1 42	....	−19·0	..	..	− 9·0	..	..	−10·0
1 43½	....	− 5·9	..	..	−13·0	..	..	+ 7·1
2 5	19901	15·8	..	18·0	..	..	− 2·2	
2 12½	....	12·6	..	..	15·0	..	..	− 2·4

Between 20,000 and 21,000 feet.

June 26 1 44	20648	−12·5	..	..	−13·0	..	..	+ 0·5

Between 21,000 and 22,000 feet.

June 26 1 46	21266	−22·8	..	..	−13·0	..	..	− 9·8

Between 22,000 and 23,000 feet.

March 31 5 27	22884	−35·4						
June 26 1 55	22965	..	10·7	..	+ 2·5			

Between 23,000 and 24,000 feet.

June 26 1 54½	....	2·5	..	..	+ 3·0	..	..	− 0·5
1 54⅔	23143	..	+ 1·8	+ 1·5	..			

TABLE X.

Heights between			Excess of Temperature of the Dew-point as found by Dry and Wet Thermometers (free) above that found by			
			Daniell's Hygrometer.	No. of obs.	Regnault's Hygrometer.	No. of obs.
feet.		feet.	°		°	
0	to	1000	−1·4	6	−0·5	4
1000	,,	2000	−0·2	22	−0·8	1
2000	,,	3000	−0·5	23		
3000	,,	4000	−1·1	15		
4000	,,	5000	−0·1	8		
5000	,,	6000	−0·5	12		
6000	,,	7000	+0·1	15		
7000	,,	8000	+1·8	1		
8000	,,	9000				
9000	,,	10000				
10000	,,	11000				
11000	,,	12000				
12000	,,	13000				
13000	,,	14000				
14000	,,	15000	+2·8	2		
15000	,,	16000	−2·0	1		
16000	,,	17000	−3·6	1	−1·9	3
17000	,,	18000				
18000	,,	19000				
19000	,,	20000	−2·2	1	−2·1	4
20000	,,	21000	....	..	+0·5	1
21000	,,	22000	....	..	−9·8	1
22000	,,	23000				
23000	,,	24000	....	..	+0·5	1

In all the experiments there seems to be no certain difference in the temperature of the dew-point as determined by Daniell's and Regnault's hygrometers, and no certain difference in the results as found by the dry- and wet-bulb free and those by the dry- and wet-bulb aspirated. The most important comparison therefore now to be made is the comparison of results by dry- and wet-bulb thermometers and with one or the other of the hygrometers.

The following are the results as found from all the simultaneous determinations of the temperature of the dew-point by Daniell's hygrometer and the dry- and wet-bulb thermometers (free).

The temperature of the dew-point by the dry- and wet-bulb (free) up to 1000 feet was the same as by Daniell's hygrometer, from 14 expts.

From 1000 to 2000 feet was 0·1 lower than by	,,	from 29	,,
2000 to 3000 feet was 0·1 lower than by	,,	from 44	,,
3000 to 4000 feet was 0·1 higher than by	,,	from 50	,,
4000 to 5000 feet was 0·4 lower than by	,,	from 30	,,
5000 to 6000 feet was 0·9 lower than by	,,	from 28	,,
6000 to 7000 feet was 0·3 lower than by	,,	from 26	,,
7000 to 8000 feet was 3·5 higher than by	,,	from 2	,,
8000 to 9000 feet there have been no determinations.			
9000 to 10,000 feet was 0·8 lower than by	,,	from 1 expt.	

At heights exceeding 10,000 feet there have not been sufficient determinations to deduce any satisfactory results, but up to 7000 feet there have been sufficient to speak confidently, and the result is that the dew-point, as found by the dry- and wet-bulb thermometers, is worthy of every confidence; for the differences, as shown above, are quite within the error of observation.

Heights and Appearances of the Clouds, and Appearances of the Sky.

March 31.

There were detached cumuli before starting; blue sky.

At 4^h 21^m 30^s p.m., at 3698 feet. Very misty; a few beautiful cumuli.

At 4^h 27^m p.m., at 6251 feet. Earth appears dotted with cumuli clouds; blue lines of light crossing each other at right angles.

At 4^h 52^m p.m., at 17,400 feet. Horizon not visible; a mass of clouds to the N.W. so distinct that its boundary-line can be traced.

April 18.

At 1^h 19^m p.m., at 2575 feet. Misty.

At 1^h 21^m 10^s p.m., at 4392 feet. Cumuli on the same level as the balloon; misty.

At 1^h 25^m 30^s p.m., at 7180 feet. Thick mist; almost a fog.

At 1^h 30^m p.m., at 11,055 feet. Above the clouds; sea of clouds below.

June 26.

From 1^h 17^m 45^s p.m., at 11,204 feet, to 1^h 25^m p.m., at 15,598 feet. In fog.

At 1^h 32^m 30^s p.m., at 17,144 feet. Clouds above us.

At 1^h 34^m p.m., at 17,479 feet. In cloud.

At 1^h 36^m p.m., at 18,291 feet. In a wetting fog.

At 1^h 37^m p.m., at 18,560 feet. Cold dry thin fog.

At 1^h 39^m p.m., at 19,018 feet. Just above cloud; cirri far above, clouds all round on the same level as the balloon.

At 1^h 41^m 45^s p.m., at 19,909 feet. Evidently three layers of clouds.

At 1^h 43^m p.m., at 20,648 feet. Rain-cloud on our right; two nimbus clouds near us and on our level.

From 1^h 43^m 30^s p.m., at 20,648 feet, to 1^h 46^m, at 21,266 feet. In fog.

At 1^h 50^m p.m., at 22,053 feet. We looked round at the faint blue sky covered with cirri, and estimated its height to be many miles; the atmosphere thick and misty.

At 1^h 54^m p.m., at 22,664 feet. Cirri clouds above; sky faint blue.

At 1^h 54^m 40^s p.m., at 23,143 feet. Above the clouds, but not free from mist; the clouds present no fine views, few peaks, and all is confused and dirty-looking. The blue sky is of the same paleness as seen from the earth.

At 1^h 5^m p.m., at 22,168 feet. The sky is faint blue, and the clouds are all below.

At 2^h 2^m p.m., at 20,167 feet. The sun seen faintly.

At 2^h 2^m 45^s p.m., at 20,167 feet. In fog.

From 2^h 4^m 30^s p.m., at 19,367 feet, to 2^h 5^m, at 19,901 feet. In fog.

At 2^h 6^m p.m., at 19,963 feet. Faint gleams of light.

At 2^h 6^m 20^s p.m., at 20,025 feet. Fog above and below, none near us; faint gleam of light.

At 2^h 7^m 30^s p.m., at 20,025 feet. Drops of water falling from the balloon on my note-book.

From 2^h 8^m 30^s p.m., at 19,089 feet, to 2^h 14^m, at 14,892 feet. In fog; at the latter time it was becoming thin, but nothing could be seen.

At 2^h 14^m 30^s p.m., at 14,501 feet. Thin rain was pattering on the balloon, and moving against us.

At 2^h 14^m 45^s p.m., at 14,197 feet. Snow-storm met with.

At 2^h 15^m p.m., at 13,380 feet. Snow falling; there were spiculæ and cross spiculæ; many snow crystals, small but distinct, all icy particles; dark everywhere.

At 2^h 15^m 30^s p.m., at 12,433 feet. Dense snow all around, no flakes; all icy particles and crystals; the appearance was beautiful.

At 2^h 15^m 45^s p.m., at 11,923 feet. When sand was thrown out the snow appeared to go up.

At 2^h 16^m p.m., at 11,412 feet. Sand presents a golden appearance when mixing with the snow.

At 2^h 17^m p.m., at 10,508 feet. No snow.

At 2^h 18^m p.m., at 10,011 feet. Lower atmosphere very murky indeed.

At 2^h 19^m p.m., at 10,011 feet. The lower atmosphere presents a brownish, yellowish tinge, remarkably dull.

At 2^h 20^m 30^s p.m., at 8107 feet. Lower atmosphere is very remarkable. Mr. Coxwell has never seen it so when far from a town.

July 11.

From 5^h 14^m p.m., at 3860 feet, to 5^h 29^m 30^s p.m., at 3642 feet. The atmosphere was thick and misty.

At 5^h 52^m 30^s p.m., at 2762 feet. Misty.

From 6^h 5^m p.m., at 3529 feet, to 6^h 14^m p.m., at 5271 feet. Misty.

At 6^h 22^m p.m., at 5884 feet. Cirrus and cirrostratus clouds far above.

At 6^h 31^m p.m., at 6328 feet. Very thick.

At 6^h 55^m 30^s p.m., at 6588 feet. Misty.

July 21.

The sky was overcast before starting.

At 4^h 52^m 30^s p.m., at 859 feet. Clouds were entered.

At 4^h 54^m p.m., at 1681 feet. Clouds very light.

At 4^h 55^m 30^s p.m., at 2351 feet. In dry cloud.

At 4^h 55^m 40^s p.m., at 2470 feet. In white cloud.

At 4^h 58^m 30^s p.m., at 2589 feet. In dense fog.

At 5^h 2^m 15^s p.m., at 2875 feet. The clouds above are darker than those below; the white edges of the lower clouds are visible.

At 5^h 7^m p.m., at 2642 feet. Lower clouds are moving in a north-easterly direction, with greater speed than the balloon.

At 5^h 8^m 15^s p.m., at 2290 feet. In cloud.

At 5^h 9^m p.m., at 2020 feet. Detached clouds below are moving in an opposite direction to that in which we were formerly moving.

At 5^h 10^m p.m., at 1727 feet. Scud below moving very fast.

At 5^h 16^m p.m., at 1890 feet. In cloud.

At 5^h 19^m 30^s p.m., at 3220 feet. There are clouds on the same level as the balloon; some clouds below are darker than those above.

At 5^h 20^m 30^s p.m., at 3298 feet. Large masses of cumulus clouds below.

At 5^h 21^m 30^s p.m., at 3218 feet. In fog.

At 5^h 23^m p.m., at 2924 feet. In wetting fog.

At 5^h 24^m p.m., at 2386 feet. Scud and clouds of a blackish colour below.

At 5^h 26^m 30^s p.m., at 1793 feet. In black cloud.

At 5^h 28^m p.m., at 1044 feet. In clouds.

At 5^h 29^m 30^s p.m., at 948 feet. Still in cloud.

At 5^h 33^m p.m., at 1179 feet. Scud far below.

At 5^h 33^m 30^s p.m., at 1507 feet. Clouds above are darker than those below.

At 5^h 37^m p.m., at 1330 feet. In cloud, very dark.

Direction of the Wind.

March 31.

At 4^h 58^m p.m., at 18,302 feet. Moving S.W.

At 4^h 58^m 30^s p.m., at 17,097 feet. Changed our course, moving N.E.

At 5^h 2^m p.m., at 17,636 feet. In a S.W. current, moving N.E.

At 5^h 12^m p.m., at 20,865 feet. In a nearly westerly current.

At 5^h 42^m 30^s p.m., at 15,714 feet. In a westerly current.

At 6^h 15^m p.m., at 4441 feet. Fell in with a S.E. current; are over Ilford.

At 6^h 16^m p.m., at 5168 feet. Changed our course, moving back again.

April 18.

Before starting the wind was N.E.

At 1^h 30^m p.m., at 11,055 feet. The wind changed to N.

June 26.

Before starting the wind was blowing W.S.W. strongly.

At 1^h 32^m p.m., at 17,144 feet. Apparently calm.

July 11.

Before starting the wind was E.

At 4^h 59^m 30^s p.m., at 2633 feet. Balloon entered a N. current.

At 7^h 14^m p.m., at 1876 feet. Balloon entered an E. current.

At 7^h 47^m p.m., at 1483 feet. Balloon again entered an E. current.

At 7^h 56^m 45^s p.m., at 1020 feet. Balloon entered a S.E. current.

At 7^h 57^m p.m., at 1000 feet. Balloon changed its course, moving W.

July 21.

Before starting the wind was S. by E.

At 5^h 7^m p.m., at 2642 feet. Balloon entered a S.W. current, moving N.E.

At 5^h 9^m 30^s p.m., at 1840 feet. Balloon turned to move back again.

Velocity of the Wind by the Balloon, and by Robinson's Anemometer at the Royal Observatory, Greenwich.

On March 31 the balloon left the Crystal Palace, Sydenham, at 4^h 16^m p.m., and fell at Barking, in Essex, a point 15 miles from the place of ascent, at 6^h 30^m p.m. Neglecting all motion of the balloon, excepting the distance between the places of ascent and descent, its hourly velocity was 7 miles; the horizontal movement of the air at Greenwich, as shown by Robinson's anemometer, was 5 miles per hour.

On April 18 the balloon left the Crystal Palace at 1^h 16^m p.m., and descended at Newhaven at 2^h 46^m. The distance is about 45 miles in $1\frac{1}{2}$ hour, or at the rate of 30 miles per hour. Robinson's anemometer had registered less than 2 miles per hour.

On June 26 the balloon left Wolverton at 1^h 2^m p.m., and fell at Littleport at 2^h 28^m p.m. The distance between these two places is 60 miles; the hourly velocity was therefore 42 miles per hour. The anemometer at Greenwich registered 10 miles per hour.

On July 11 the balloon left the Crystal Palace at 4^h 53^m p.m., and fell at Goodwood at 8^h 50^m p.m., having travelled 70 miles, or at the rate of 18 miles per hour. The anemometer at Greenwich registered less than 2 miles per hour.

On July 21 the balloon left the Crystal Palace at 4^h 52^m p.m., and fell near Waltham Abbey, having travelled about 25 miles in 53 minutes, or at the rate of 29 miles per hour. The horizontal movement of the air by Robinson's anemometer was at the rate of 10 miles per hour.

Propagation of Sound.

March 31.

At 5^h 57^m 30^s p.m., at 13,614 feet. Heard some sounds.

At 6^h 3^m p.m., at 10,917 feet. A railway train heard.

June 26.

At 1^h 16^m p.m., at 8888 feet. There was a sighing or moaning of the wind heard as preceding a storm; this continued for some time, and is the first instance of the kind that either Mr. Coxwell or myself have experienced. It was in no way owing to the cordage of the balloon, but appeared to be beneath, as if from conflicting currents below us.

At 1^h 31^m 30^s p.m., at 16,442 feet. A railway train heard.

At 1^h 48^m p.m., at 21,978 feet. A railway train heard.

July 11.

At 5^h 19^m p.m., at 4000 feet. The cheering of people at Caterham heard.

At 6^h 20^m p.m., at 5772 feet. People heard shouting.

At 7^h 56^m 30^s p.m., at 1000 feet. Cries of "come down" heard.

At 8^h 1^m 30^s p.m., at 808 feet. A pack of hounds baying at us.

At 8^h 4^m p.m., at 1241 feet. Frightened geese heard cackling.

At 8^h 9^m p.m., at 1145 feet. A bugle heard.

At 8^h 14^m p.m., at 1532 feet. Bugle heard again.

July 21.

At 5^h p.m., at 2488 feet. A railway train and the hum of London heard; also bell tolling 5 o'clock heard.

At 5^h 1^m p.m., at 2610 feet. Hammering heard.

Physiological Observations.

March 31.

At 4^h 46^m 30^s p.m., at 16,669 feet. Mr. Glaisher's heart beats very loud, but not Mr. Coxwell's.

At 5^h p.m., at 17,205 feet. Face very blue; feet very cold.

At 5^h 24^m+p.m., at 20,910 feet. Breathing deeply.

At 5^h 25^m p.m., at 21,860 feet. Hands blue.

At 5^h 31^m p.m., at 16,486 feet. Mr. Glaisher's pulsations 97 per minute; Mr. Coxwell's 98 per minute.

At 5^h 47^m 40^s p.m., at 16,080 feet. Very cold.

At 6^h p.m., at 11,953 feet. Mr. Coxwell's hands felt as if they were scalded; he was unable to lower the grapnel.

At 6^h 3^m p.m., at 10,917 feet. Face a glowing purple.

At 6^h 5^m p.m., at 9570 feet. Violent retching.

At 6^h 8^m p.m., at 7907 feet. A feeling of illness.

At 6^h 9^m p.m., at 7443 feet. Vomiting.

April 18.

At 1^h 42^m p.m., at 17,057 feet. A stream of cold to sense.

At 1^h 48^m p.m., at 18,886 feet. A general tinge over the countenance; heart slightly affected.

At 1^h 52^m 50^s p.m., at 20,163 feet. Face of a bluish-white colour.

At 2^h p.m., at 20,943 feet. Mr. Glaisher's pulsations varied from 90 to 95 per minute; Mr. Coxwell's from 98 to 113; Mr. Ingelow's kept at 130. Mr. Glaisher's pulse was weak; Mr. Ingelow's full and strong.

At 2^h 13^m p.m., at 21,760 feet. Air very dry to sense.

June 26.

At 1^h 7^m 20^s p.m., at 3029 feet. It was painfully cold.

At 1^h 11^m p.m., at 6477 feet. Dreadfully cold; I put on a coat with difficulty; wrapped up my neck; also put on an extra cap, and gave Mr. Coxwell a wrapper.

At 1^h 22^m p.m., at 14,203 feet. Mr. Coxwell complained of pains in his hands, which were of a dark-blue colour.

The Lines in the Spectrum.

March 31.

Before starting B was the boundary-line at the red end, and a little past G at the violet end when looking at the sky. When looking at the sun H was not distinctly seen.

At 4^h 20^m p.m., at about half a mile high. The spectrum was the same as on the earth, but the extreme lines were seen with less distinctness.

At 4^h 29^m p.m., at 7557 feet. Sky spectrum very bright, less lines at the red and violet ends. G is quite the limit, B cannot be seen, and C is doubtful.

At 4^h 39^m p.m., at 12,000 feet. Can see to the line F in the sky spectrum; violet dull; no lines can be seen beyond D.

At 4^h 42^m p.m., at 13,700 feet. Lost sight of the violet end of the sky spectrum; no lines can be seen at all.

At 4^h 45^m p.m., at 15,793 feet. Sky spectrum very short; no lines; can see a little beyond D to E, not F.

At 4^h 49^m p.m., at 17,616 feet. No lines visible in the sky spectrum; faint violet rays as far as G.

At 5^h 10^m p.m., at 19,356 feet. No sky spectrum at all.

At 5^h 23^m p.m., at 20,749 feet. No sky spectrum at all.

At 5^h 43^m p.m., at 16,080 feet. No sky spectrum at all.

At 5^h 58^m 30^s p.m., at 12,797 feet. No sky spectrum; probably not sufficient light.

April 18.

Before starting the solar spectrum extends from B to nearly H, and the sky spectrum from B to G; these lines were quite the limit.

At $1^h\ 20^m$ p.m., at 3555 feet. The spectroscope was directed to the sky near the sun; G was very clear; can see H and far beyond.

At $1^h\ 21^m\ 10^s$ p.m., at 4392 feet. Very mary lines in the sky spectrum; the line B is clear.

At $1^h\ 27^m$ p.m., at 7764 feet. Sky spectrum from B up to A.

At $1^h\ 27^m\ 30^s$ p.m., at 7764 feet. Beyond H and A in the sky spectrum, under and near the sun, lines beautifully defined; requires great change of focus to see A and H. When spectrum is directed at some distance from the sun can see B and several lines beyond.

At $1^h\ 29^m$ p.m., at 10,020 feet. Sky spectrum short.

At $1^h\ 53^m$ p.m., at 20,163 feet. Examined slit of apparatus; all seems right.

At $2^h\ 12^m$ p.m., at 21,646 feet. No sky spectrum; no lines.

At $2^h\ 15^m$ p.m., at 22,041 feet. Solar spectrum extended a good way beyond H at the violet end. On passing from the sun the spectrum shortened, and G was the limit; this was soon lost and the spectrum shortened rapidly.

At $2^h\ 15^m$ p.m., at 22,041 feet. On approaching the sun again the yellow first appeared, and when very near the sun on all sides the spectrum was perfect, increasing in length the nearer it approached the sun; and when a beam of light came from the sun itself the whole spectrum was visible, and many lines between A and *a* and *a* and B. On passing from the sun the same phenomena were repeated as before; and when the sun again came round, from A to a good way beyond H was examined, and every line was seen that was visible from the earth, and a good many more.

June 26.

At the highest point the sky spectrum was the same as on the earth.

July 11.

At $5^h\ 28^m$ p.m., at 3581 feet. Sky spectrum from B to G seen.

Different Appearances of the Gas.

March 31.

At $4^h\ 41^m$ p.m., at 13,070 feet. Gas very thick.
At $4^h\ 47^m$ p.m., at 17,060 feet. Gas issuing from the neck of the balloon.
At $4^h\ 48^m$ p.m., at 17,451 feet. Gas yellow and opaque.
At $5^h\ 57^m$ p.m., at 13,614 feet. Gas very clear.

April 18.

At $1^h\ 38^m$ p.m., at about 15,000 feet. Gas clear.
At $1^h\ 54^m$ p.m., at 20,163 feet. Gas clear.

June 26.

At $1^h\ 33^m$ p.m., at 17,242 feet. Gas seen rushing out of the balloon in volumes.

July 21.

At $4^h\ 55^m$ p.m., at 2095 feet. Gas very cloudy.
At $4^h\ 59^m$ p.m., at 2550 feet. Gas getting clearer.

At 5^h 19^m 30^s p.m., at 3220 feet. Gas thick and opaque.

At 5^h 26^m 30^s p.m., at 1793 feet. Gas beautifully clear, so that the netting can be seen through the balloon.

At 5^h 34^m 15^s p.m., at 1960 feet. Gas thick and opaque.

Miscellaneous Observations.

March 31.

At 4^h 24^m p.m., at 5296 feet. London looks beautiful; Isle of Dogs visible at about the distance of one mile.

At 4^h 46^m 30^s p.m., at 16,669 feet. The sun's shape well defined as reflected in the water; St. Katherine's Docks apparently 10 miles distant; the Crystal Palace apparently nearly under us.

At 4^h 50^m p.m., at 18,304 feet. The earth looks beautiful; the mouth of the Thames appears almost under us; the coast is visible to Dover; can see Brighton and the sea beyond.

At 4^h 52^m p.m., at 17,400 feet. Just over Isle of Dogs; the Royal Observatory visible; the Green Man Hotel, Blackheath, distinct; can see the rippling of the water below Putney Bridge.

At 5^h 4^m p.m., at 18,293 feet. Apparently over the Isle of Dogs.

At 5^h 8^m 50^s p.m., at 19,197 feet. Apparently over Victoria Docks.

At 5^h 26^m p.m., at 22,068 feet. Mouth of the Thames visible, and the coast is clear to Yarmouth.

At 5^h 34^m p.m., at 15,149 feet. The Thames and country visible for miles.

At 5^h 45^m p.m., at 16,080 feet. Chelmsford in sight.

At 5^h 46^m p.m., at 16,080 feet. East coast clear; Ipswich in sight.

At 5^h 52^m p.m., at 15,630 feet. Darkness is creeping over the earth.

At 6^h 24^m p.m., at 1260 feet. Over Romford or Ilford.

At 6^h 25^m 30^s p.m., at 893 feet. Packed up the instruments in a hurry.

April 18.

At 1^h 21^m 10^s p.m., at 4392 feet. Crystal Palace and grounds well seen.

At 1^h 33^m p.m., at 12,970 feet. Balloon full.

At 1^h 48^m p.m., at 18,886 feet. The largest field appears to be three inches square; lowered the grapnel.

At 2^h 31^m 30^s p.m., at 23,324 feet. Looked at the sun with red, blue, and yellow glass for anything like prominences; edge without appendages of any kind.

June 26.

At 2^h 20^m 20^s p.m., at 9148 feet. Two canals in sight; straight for many miles.

July 11.

At 5^h 36^m p.m., at 2332 feet. Over Epsom Downs.

At 5^h 37^m p.m., at 2469 feet. About five miles from Reigate.

At 5^h 39^m p.m., at 2424 feet. Sand out.

At 5^h 43^m 30^s p.m., at 2488 feet. The two towers of the Crystal Palace not quite in a straight line with us.

At 5^h 45^m p.m., at 2488 feet. Sand out.

At 5^h 49^m p.m., at 2820 feet. Near Reigate.

At 5^h 51^m p.m., at 2762 feet. A very fine view; crossing high road.

At 6^h 4^m p.m., at 3250 feet. Sand out.

At 6^h 13^m p.m., at 5105 feet. Sand out.

At 6^h 16^m p.m., at 5382 feet. Over Horsham.

At 6^h 52^m p.m., at 6453 feet. The coast at Brighton is distinctly visible.

At 7^h 7^m 30^s p.m., at 3645 feet. Near Newhaven.

At 8^h 6^m 30^s p.m., at 1144 feet. Over a very extensive wood.

At 8^h 7^m 15^s p.m., at 1048 feet. We are apparently four or five miles from the coast.

At 8^h 14^m p.m., at 1532 feet. Goodwood Park visible.

At 8^h 32^m 30^s p.m., at 666 feet. Over Goodwood Park.

At 8^h 34^m p.m., at 1085 feet. Packed up instruments.

July 21.

At 4^h 52^m 10^s p.m. Balloon left the earth.

At 4^h 53^m p.m., at 1439 feet. Crystal Palace still visible.

At 5^h 5^m p.m., at 2890 feet. Docks and River Thames visible; ships visible; over Greenwich.

At 5^h 6^m p.m., at 2750 feet. Over West India Docks.

At 5^h 11^m 30^s p.m., at 1300 feet. Over Walthamstow; carts visible.

At 5^h 12^m p.m., at 1120 feet. Nearly over Victoria Park.

At 5^h 12^m 15^s p.m., at 1030 feet. Over East London Cemetery.

At 5^h 29^m 30^s p.m., at 948 feet. Can hear the pattering of rain on the trees of Epping Forest.

At 5^h 35^m p.m., at 1898 feet. The grapnel and half the rope are invisible.

At 5^h 39^m p.m., at 996 feet. Changed direction, passing over the Forest; can see sheep clearly.

Meteorological Observations made in connexion with the Balloon Ascent on

March 31.

ROYAL OBSERVATORY, GREENWICH.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
h m	in.	°	°	°	in.					
2 0 p.m.	30·09	47·8	42·2	36·0	·212	64	E.S.E.	5	0	Cirrus, cumulus, cirrostratus, [and cirrocumulus.
2 10 ,,	30·09	49·6	44·4	38·8	·236	67	S.E.	5	...	
2 20 ,,	30·09	50·4	44·2	37·6	·225	62	...	4	...	Cirrus, cumulus, cirrostratus and cumulostratus.
2 30 ,,	30·08	49·8	43·8	37·4	·224	63	E.	4	...	
2 40 ,,	30·08	49·8	43·8	37·4	·224	63	E.S.E.	5	...	
2 50 ,,	30·08	48·3	42·6	36·4	·215	63	S.E.	6	...	
3 0 ,,	30·08	47·0	41·6	35·5	·208	65	...	5	0	Cirrus, cumulus, cirrocumulus, cirrostratus, and cumulostratus.
3 10 ,,	30·08	49·3	43·1	36·4	·215	61	S.S.E.	5	...	
3 20 ,,	30·08	50·5	44·3	37·7	·226	62	S.S.E.	6	...	
3 30 ,,	30·08	48·3	42·6	36·3	·214	63	S.E.	4	...	Cirrus, cirrocumulus, and cirrostratus.
3 40 ,,	30·08	48·1	42·4	36·1	·213	63	...	4	...	
3 50 ,,	30·08	48·5	42·8	36·5	·216	63	...	2	...	Cirrus, cumulus, and cirrostratus.
4 0 ,,	30·08	48·4	42·7	36·4	·215	64	...	2	0	
4 10 ,,	30·07	47·8	42·3	36·2	·214	65	E.S.E.	0	...	Cloudless, with the exception of a little cirrus and cumulostratus.

Meteorological Observations made in connexion with the Balloon Ascent on

March 31 (*continued*).

Royal Observatory, Greenwich.

Time of observation.	Reading of Barom. reduced to 32° F.	Thermom. Dry.	Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
h m	in.	°	°	°	in.					
4 20 p.m.	30·07	47·6	42·3	36·4	·215	66	...	0	...	Balloon seen to rise; it then took a westerly direction.
4 30 ,,	30·07	47·5	42·2	36·3	·214	65	...	0	...	About this time the balloon changed, and took a direction nearly E.N.E.
4 40 ,,	30·07	46·3	41·3	35·6	·208	67	...	0	...	
4 50 ,,	30·07	45·5	40·4	34·5	·199	65	...	0	0	Cloudless. Sand appeared to rise above the balloon.
5 0 ,,	30·07	45·6	40·7	35·1	·196	67	...	0	...	Cloudless. Balloon exactly over the Royal Observatory. It was moving in a direction nearly E.S.E.
5 10 ,,	30·07	44·5	39·3	33·2	·189	64	...	0	...	On looking through the 30 in. achromatic telescope, the face and shoulders of one of the aëronauts were seen.
5 20 ,,	30·07	44·1	39·1	33·2	·189	65	...	0	...	Ballast thrown out. The netting of balloon distinctly seen by aid of telescope.
5 30 ,,	30·07	43·6	38·6	32·6	·185	65	...	0	...	Cloudless. Balloon E.N.E. of Royal Observatory.
5 40 ,,	30·07	43·4	38·4	32·5	·184	65	...	0	...	
5 50 ,,	30·08	42·7	38·1	32·5	·184	67	...	0	...	
6 0 ,,	30·08	42·4	37·7	32·0	·181	68	...	0	0	
6 10 ,,	30·08	42·2	37·5	31·8	·179	68	...	0	...	
6 20 ,,	30·08	41·9	37·3	31·7	·179	67	...	0	...	
6 30 ,,	30·08	41·1	36·9	31·7	·179	69	...	0	...	
6 40 ,,	30·08	40·6	36·7	31·7	·179	71	...	0	...	
6 50 ,,	30·08	40·3	36·5	31·6	·178	71	...	0	...	
7 0 ,,	30·08	40·0	36·3	31·5	·177	71	E.S.E.	0	...	
9 0 ,,	30·09	37·1	34·4	29·8	·166	77	S.E.	0	0	Cloudless; a very fine bright evening.

April 18.

Royal Observatory, Greenwich.

Time of observation.	Reading of Barom. reduced to 32° F.	Thermom. Dry.	Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
Noon.	30·09	60·2	54·2	48·9	·346	66	N.N.E.	10	0	Generally overcast; light clouds
0 10 p.m.	30·09	59·6	53·7	48·5	·342	68	...	8	...	Cirrus, cirrocumulus, and cumulostratus.
0 20 ,,	30·09	61·2	55·6	50·7	·370	69	...	7	...	
0 30 ,,	30·09	61·6	55·7	50·6	·369	69	...	10	...	
0 40 ,,	30·09	60·4	55·3	50·9	·373	71	N.E.	6	...	Cirrus, cirrocumulus; dense cirrostratus in S.E.; clear in N.
0 50 ,,	30·09	62·9	56·3	50·7	·370	65	...	6	...	Cirrus, cumulus, cirrostratus, and cirrocumulus.
1 0 ,,	30·09	62·2	56·0	50·6	·369	66	N.N.E.	7	0	
1 10 ,,	30·09	61·5	55·8	50·9	·373	69	N.E.	8	...	Cirrus, cirrostratus, and cirrocumulus.
1 20 ,,	30·10	59·2	54·2	49·7	·357	71	...	8	...	
1 30 ,,	30·10	58·7	53·6	49·0	·348	70	...	8	...	
1 40 ,,	30·10	58·2	52·9	48·1	·336	70	...	7	...	Cirrus, cumulus, cumulostratus, and cirrostratus.
1 50 ,,	30·10	59·7	53·6	48·2	·338	66	N.N.E.	7	...	
2 0 ,,	30·10	58·8	59·3	48·3	·339	67	...	6	0	
2 10 ,,	30·10	59·3	53·5	48·4	·340	68	...	5	...	

Meteorological Observations made in connexion with the Balloon Ascent on

April 18 (*continued*).

Royal Observatory, Greenwich.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
h m	in.	°	°	°	in.					
2 20 p.m.	30·10	59·1	53·2	48·0	·335	67	...	6	...	Cirrus, cumulus, cirrocumulus, and cirrostratus.
2 30 ,,	30·10	61·9	55·1	49·3	·352	63	N.E.	6	...	
2 40 ,,	30·10	59·2	53·0	47·5	·329	65	...	5	...	
2 50 ,,	30·10	59·7	53·3	47·6	·330	65	N.N.E.	4	...	Cirrus, cumulus, cirrocumulus, and cumulostratus.
3 0 ,,	30·10	60·6	54·2	48·6	·343	65	...	4	0	
3 30 ,,	30·09	58·1	51·8	46·1	·312	65	...	6	...	Cirrus, cirrocumulus, cumulus, and cumulostratus.
3 40 ,,	30·10	57·4	51·4	46·0	·311	65	...	5	...	
3 50 ,,	30·10	57·7	52·0	46·8	·321	67	...	5	...	
4 0 ,,	30·10	58·1	51·8	46·1	·312	65	N.N.E.	6	0	

June 26.

Royal Observatory, Greenwich.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
Noon.	30·00	72·4	59·4	49·7	·357	45	W.S.W.	4	2	Cumulus, cirrocumulus, and cirrus.
0 10 p.m.	30·00	72·5	60·4	51·4	·379	48	W.S.W.	4	...	
0 20 ,,	29·99	71·2	60·3	52·0	·388	51	S.W.	5	...	Cumulus, cirrus, and cirrocumulus in the zenith.
0 30 ,,	29·99	72·4	61·1	52·7	·399	50	W.	4	...	Cumulus, cirrocumulus, and cirrus; the zenith is clear.
0 40 ,,	29·99	73·3	62·0	53·7	·413	50	W.	5	...	Cumulus; cirrocumulus in the zenith and cirrus.
0 50 ,,	29·99	73·2	62·9	55·3	·437	53	W.S.W.	5	...	
1 0 ,,	29·99	72·9	61·2	52·6	·397	49	...	4	...	Cirrus and cirrocumulus.
1 10 ,,	29·98	74·0	62·5	54·1	·419	50	...	5	...	
1 20 ,,	29·98	73·4	61·8	53·3	·407	49	W.S.W.	5	...	Cirrus, cirrostratus, and cirrocumulus.
1 30 ,,	29·98	72·4	60·7	52·0	·388	49	W.	6	...	
1 40 ,,	29·98	72·5	61·1	52·6	·397	50	W.S.W.	6	...	
1 50 ,,	29·98	73·9	61·5	52·5	·396	47	W.	4	...	
2 0 ,,	29·98	73·1	61·5	52·9	·401	50	W. by S.	4	...	
2 10 ,,	29·97	72·1	60·7	52·1	·389	50	W.	8	...	Cirrocumulus, cirrostratus, and cirrus.
2 20 ,,	29·97	72·0	60·0	51·0	·374	48	W.	8	...	
2 30 ,,	29·97	70·8	59·5	50·8	·371	50	W.	9	...	Cirrocumulus, cirrostratus, and cirrus.
2 40 ,,	29·97	70·7	59·0	50·0	·361	48	W. by S.	9	...	Cirrocumulus, cirrus, and cirrostratus.
2 50 ,,	29·97	72·4	61·1	52·7	·399	50	W.S.W.	10	...	Overcast; cirrostratus principally, with a little cirrus and cirrocumulus.
3 0 ,,	29·97	70·2	59·0	50·4	·366	49	W. by S.	10	0	
3 10 ,,	29·96	69·4	58·7	50·5	·367	51	W. by S.	10	...	
3 20 ,,	29·96	69·4	59·1	51·1	·375	52	W. by S.	10	...	
3 30 ,,	29·96	68·9	58·9	51·1	·375	52	W.	10	...	Overcast; nearly all cirrostratus.
3 40 ,,	29·96	68·3	58·2	50·3	·365	52	W.N.W.	10	...	
3 50 ,,	29·96	67·1	58·5	51·6	·382	58	W.N.W.	10	...	
4 0 ,,	29·96	67·0	58·1	51·0	·374	56	W.N.W.	10	0	
4 10 ,,	29·96	66·7	58·6	52·0	·389	60	W.N.W.	10	...	Overcast; cirrostratus; sun shining faintly through the cloud.
4 20 ,,	29·96	65·3	57·5	51·1	·375	60	W.N.W.	10	...	Overcast; cirrostratus.
4 30 ,,	29·96	64·5	56·5	49·9	·360	59	N.W.	10	...	
4 40 ,,	29·96	63·9	56·3	50·0	·361	60	N.W.	10	...	Overcast; few drops of rain.
4 50 ,,	29·96	62·7	56·2	50·6	·369	65	N.W.	10	...	
5 0 ,,	29·96	61·8	55·9	56·9	·373	69	N.W.	10	0	Overcast; continuous rain.

Meteorological Observations made in connexion with the Balloon Ascent on

June 26 (*continued*).

WOLVERTON.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
h m	in.	°	°	°	in.					
0 55 p.m.	29·85	67·3	59·0	52·4	·394	59	Wind unknown.			Balloon in sight; very cloudy; [brisk wind.
1 0 „	29·83	67·0	61·0	56·2	·453	68		10	...	
1 15 „	29·83	67·8	58·0	50·2	·364	53		10	...	Balloon out of sight at 1h 18m; cloudy.
1 25 „	29·83	65·9	57·3	50·2	·364	57		10	...	
1 30 „	29·82	66·4	57·8	50·8	·371	58		10	...	
1 35 „	29·82	66·0	56·6	48·9	·346	54		10	...	
1 40 „	29·82	66·0	57·3	50·2	·364	57		10	...	
1 45 „	29·83	65·2	57·0	50·7	·370	60		10	...	Cloudy.
1 50 „	29·82	65·0	57·0	50·4	·366	59		10	...	
1 55 „	29·81	64·5	57·0	52·1	·389	65		10	...	
2 0 „	29·81	65·0	57·0	50·4	·366	59		10	...	
2 5 „	29·82	64·8	57·0	52·6	·397	66		10	...	Clouds thicker.
2 10 „	29·83	64·7	56·3	50·4	·366	61		10	...	
2 20 „	29·83	63·4	55·8	48·3	·339	58		10	...	
2 25 „	29·83	63·4	55·8	48·3	·339	58		10	...	
2 30 „	29·84	63·7	55·8	49·1	·349	59		10	...	Raining.
2 40 „	29·84	64·0	56·0	49·4	·351	59		10	...	
2 45 „	29·82	62·0	57·0	52·7	·399	72		10	...	
2 50 „	29·82	63·0	57·0	51·9	·387	67		10	...	
2 55 „	29·82	63·0	57·0	51·9	·387	67		10	...	
3 0 „	29·82	62·8	57·0	54·2	·421	76		10	...	
3 5 „	29·82	61·3	56·0	52·2	·391	74		10	...	Little rain.
3 10 „	29·82	61·0	55·2	49·6	·356	66		10	...	
3 15 „	29·82	61·0	55·0	49·8	·358	67		10	...	
3 20 „	29·82	61·0	54·3	47·7	·332	61		10	...	
3 25 „	29·82	60·0	54·0	48·7	·344	66		10	...	
3 30 „	29·82	59·9	54·0	48·7	·344	66		10	...	No rain.
3 35 „	29·82	60·0	54·0	48·7	·344	66		10	...	
3 40 „	29·82	60·8	54·4	49·9	·360	68		10	...	
3 45 „	29·82	60·0	54·0	48·7	·344	68		10	...	Raining fast.
3 50 „	29·82	60·0	53·3	47·0	·318	61		10	...	
3 55 „	29·80	59·0	53·3	47·7	·330	69		10	...	
4 0 „	29·80	59·0	53·2	47·9	·328	65		10	...	

July 11.

ROYAL OBSERVATORY, GREENWICH.

Noon.	30·23	76·8	66·5	59·2	·503	55	E.S.E.	5	0	Cirrus and haze principally; a little cirrostratus.
0 10 p.m.	30·23	76·6	66·4	59·2	·503	55	E.S.E.	5	...	
0 20 „	30·22	77·2	66·1	58·4	·489	53	E.	5	...	
0 30 „	30·22	77·2	66·1	58·4	·489	53	E.S.E.	6	...	
0 40 „	30·22	77·2	65·8	57·9	·480	52	E. by N.	6	...	
0 50 „	30·22	76·0	64·3	56·0	·449	50	S.E.	5	...	
1 0 „	30·22	77·2	64·8	56·1	·451	50	S.E.	6	0	
1 10 „	30·22	77·8	64·7	55·6	·443	48	E.S.E.	6	...	
1 20 „	30·22	76·8	63·8	54·1	·419	46	E.S.E.	5	...	
1 30 „	30·20	76·7	63·5	54·3	·422	47	S.E.	6	...	Cirrus and haze principally; a little cirrostratus.
1 40 „	30·21	76·2	63·0	53·7	·413	46	S.E.	7	...	

Meteorological Observations made in connexion with the Balloon Ascent on

July 11 (*continued*).

ROYAL OBSERVATORY, GREENWICH.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
h m	in.	°	°	°	in.					
1 50 p.m.	30·21	77·3	63·2	53·3	·407	44	E.S.E.	9	...	Cirrus and haze.
2 0 "	30·21	77·3	62·9	52·8	·400	43	E.	9	0	Cirrus, cirrostratus, and haze.
2 10 "	30·21	76·1	62·2	52·3	·393	44	E.S.E.	9	...	Cirrus, cirrocumulus, and haze.
2 20 "	30·21	75·8	61·6	51·4	·379	43	E.	9	...	
2 30 "	30·21	73·7	61·4	52·4	·394	47	E.	10	...	Overcast, with light cloud, chiefly cirrostratus.
2 40 "	30·21	73·9	61·7	52·8	·400	47	S.E.	10	...	
2 50 "	30·20	73·3	61·2	52·2	·391	48	S.E.	9	...	Cirrostratus and a little cirrocumulus.
3 0 "	30·20	74·4	61·8	52·7	·399	46	S.E.	9	0	
3 10 "	30·20	75·1	62·1	52·7	·399	46	E.S.E.	9	...	
3 20 "	30·20	74·6	61·6	52·1	·389	46	E.	8	...	
3 30 "	30·20	74·5	61·5	51·1	·389	46	S.E.	8	...	
3 40 "	30·19	74·1	61·2	51·7	·384	46	E.S.E.	8	...	
3 50 "	30·19	73·8	60·6	50·9	·373	45	E.S.E.	8	...	Cirrostratus.
4 0 "	30·19	74·1	61·0	51·4	·379	45	E.	8	0	Cirrostratus; the blue sky has been in the S.E. since the clouds first began to break.
4 10 "	30·19	74·1	61·1	51·6	·382	45	E.S.E.	8	...	
4 20 "	30·19	74·3	60·9	51·1	·375	44	E.S.E.	8	...	Cirrus and cirrostratus.
4 30 "	30·19	74·5	60·8	50·9	·373	44	E.	8	...	
4 40 "	30·19	74·8	60·9	50·8	·371	43	E.	7	...	
4 50 "	30·18	74·9	61·0	51·0	·374	43	E.S.E.	7	...	
5 0 "	30·18	74·1	61·3	51·9	·386	46	E.S.E.	6	...	
6 0 "	30·18	69·9	60·6	53·4	·409	55	S.E.	9	...	Thin cirrus and cirrostratus generally prevalent.
9 0 "	30·19	62·5	58·0	54·2	·421	75	S.E.	1	2	Few light clouds scattered here and there.

July 21.

ROYAL OBSERVATORY, GREENWICH.

Time of observation.	Reading of Barom. reduced to 32° F.	Reading of Thermom. Dry.	Reading of Thermom. Wet.	Temp. of the dew-point.	Tension of vapour.	Degree of humidity.	Direction of wind.	Amount of cloud 0–10.	Amount of ozone.	Remarks.
5 10 p.m.	29·52	61·0	61·5	61·0	·537	100	S.S.E.	10	3	Overcast; rain has fallen almost continuously since 3 o'clock; thin rain falling.
5 20 "	29·52	61·0	61·5	61·0	·537	100	S.S.E.	10	...	Overcast.
5 30 "	29·52	61·2	60·7	60·1	·520	97	S.S.E.	10	...	
5 40 "	29·51	61·2	60·7	60·1	·520	97	S.S.E.	10	...	
5 50 "	29·51	60·9	60·5	60·3	·524	98	S.S.E.	10	...	Overcast; rain just commenced falling heavily.
6 0 "	29·51	60·9	60·5	60·3	·524	98	S.S.E.	10	3	Overcast; rain still falling.
6 10 "	29·51	60·7	60·3	60·0	·518	98	S.S.E.	10	...	
6 20 "	29·50	60·5	60·2	60·0	·518	98	S.S.E.	10	...	
6 30 "	29·50	60·4	60·2	60·1	·520	99	S.S.E.	10	3	

Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America. By PHILIP P. CARPENTER, *B.A., Ph.D.** K. ref.

THE object of the present Report is (1) to correct the errors which have been observed in the first Report ("Report &c." 1856, pp. 159–368); and (2) to point out the fresh sources of information which have been rendered available since that period. For convenience of comparison, the paragraph numbers refer to those of the first Report in the corrections, and are continued from them in the addenda. In the bibliographical portion, the criticisms by the writer of this Report are inserted in [ ]; a distinction not always attended to in the former volume, in consequence of which erroneous names and localities have been attributed to the reviewer, instead of to the authors quoted.

22. *Introduction.*—(Line 4 from bottom.) The river Willamette flows *northwards* (Gld.).

23. *Early Writers.*—The only Californian shell described by Linnæus is *Turbo sanguineus*, = *T. coccineus*, Desh.; v. Hanl. Ips. Linn. Conch. p. 334. The types are too much worn to decide whether they came from the North Pacific or (as is more probable) from the Mediterranean. In Gmelin's edition of Linnæus, *Lipsiæ*, 1788–1790,—which is, in great measure, a translation from a German work published a few years in advance [teste Hanley],—the following species are assigned to the "West Coast of America," probably on the authority of Martyn:—page 3529, *Murex foliatus*: 3702, *Patella pecten*: 3712, *Patella calyptra*. The last two seem exotic.

Many West-coast species had found their way into English collections during the last century, at a much earlier date than was expected at the time of the first Report. They were mainly derived from the voyages of Capt. Cook and other circumnavigators. Capt. Cook was accompanied by Solander, as naturalist, at the instance of Sir Joseph Banks. His shells passed into the hands of Mr. Humphrey, the dealer, at whose death the remainder, a thousand boxes, became the property of the elder Sowerby, and (in part) of Mawe [teste Hanley]. They took their chance of being figured or described by the early conchologists. The localities are (as might be expected) often interchanged, but have been quoted by later authors, who have not thought fit to avail themselves of more correct sources of information.

The first accurate delineations are by Thomas Martyn, in his 'Universal Conchologist,' London, 1784. Those who only know this book from Chenu's reprint, Paris, 1845, can form but a poor idea of the exquisite beauty of the original work. Of this, very few copies are accessible; but it may be consulted at the British Museum, the Royal Society, and the Royal College of Surgeons.

No.	Plate.	Fig.	
16	5	3.	*Patella tramoserica*, Mart. N.W. C. America, very rare. [N. Zealand.]
18	6	1.	*Patella calyptra*, Mart. N.W. Coast of America, very rare. [Not identified: resembles *Crep. adunca*, without deck. Hanl. considers it a *Hipponyx*, like *australis*.]
31	8	4.	*Trochus inæqualis*, Mart. Friendly Isles, common. [Does not closely resemble the Japan and Vancouver species, = *Pachypoma gibberosum*, Chemn.]
32	10	1.	*Trochus canaliculatus*, Mart. N. Zealand, rare.
33	10	2.	*Trochus annulatus*, Mart. N. Zealand, very rare.
34	10	3.	*Trochus costatus*, Mart. St. George's Sound, rare. [= *Calliostoma filosum*, *castaneum*, *ligatum*, and *modestum*.]

* In consequence of the expected arrival of fresh materials, this Report has been corrected and continued up to the period of going to press.
Warrington Free Museum and Library, Aug. 1st, 1864.

No.	Plate.	Fig.	
43	13,14	1.	*Buccinum liratum*, Mart. St. George's Sound, most rare. [=*F. decemcostatus* (Say), Midd., =*Middendorffii*, Cooper.]
44	13	2.	*Buccinum plicatum*, Mart. [non Linn.] St. George's Sound, common. [=*crispatum*, + *compositum*, Chemn., =*lactuca*, &c., Esch.]
46	15	1.	*Buccinum lima*, Mart. St. George's Sound, rare. [Probably *P. decemcostata*, Midd.; the variety with numerous ribs and flattened spire.]
47	15	2.	*Buccinum saturum*, Mart. St. George's Sound, most rare. [Like *Chr. liratus*, with keels evanescent.]
62	20	2.	*Haliotis pulcherrima*, Mart. St. George's Sound, most rare. [Pacific Is.]
66	24	1.	*Purpura foliata*, Mart. North-west Coast of N. America, rare.
76	26	4.	*Trochus pulligo*, Mart. St. George's Sound, common.
80	28	2.	*Pectunculus corbis*, Mart. Pulo-Condore, most rare. [= *Cardium Nuttallii*, Conr., teste Desh. Cum. The figure is not so accurate as most of the others; but the colouring is characteristic.]
153	53	1.	*Pecten rubidus*, Mart. [non Hds.] Newfoundland, rare. [=*P. Islandicus*, Müll.]

Many of the figures of Martyn were reproduced by Chemnitz, in his comprehensive continuation of Martini's 'Conchylien Cabinet,' 1780–1795. Unhappily, though often quoted for generic and specific names, he did not adopt the binomial nomenclature (except in vol. xi.), but described each shell in two or more words, as it happened. For this reason he appears to have had no scruple in altering previous designations, as follows:—

Fig.

1538, 1539. *Murex Purpura alata*, "Mart. Conch. Un. vol. ii. f. 66, Leaved *Purpura foliata* from N.W. coast of America."

1634 .. *Murex Glomus cereus*, seu *Cereus conglomeratus*, "Mart. vol. ii. f. 43, Ridged *Buccinum liratum* from King George's Sound."

Vign. 21, f. A, B. *Buccinum compositum*, "Mart. Un. Conch. vol. ii. f. 44; Plaited *Buccinum* from King George's Sound."

Vign. 23, f. A, B. *Trochus gibberosus Novæ Zelandiæ.* "Forster's Cat. no. 1374; La Raboteuse de la nouvelle Zélande.—Mart. Un. Conch. vol. i. f. 31; Rugged *Trochus inæqualis* from Friendly Is."

1579, 1580. *Trochus doliarius*, "Mart. vol. i. f. 32, Fluted *Trochus canaliculatus* from N. Zealand."

1581, 1582. *Trochus virgineus*, "Favanne, Conch. pl. 79. f. 1. vol. ii. p. 342; id. Cat. Rais. no. 1352, p. 269; Le Sabot Magellanique.—Mart. Un. Conch. vol. i. f. 33; Ringed *Trochus annulatus* from N. Zealand.—Cab. Mus. Portl. no. 1240; the Purpled-edged *Trochus*; item, no. 1970, a large and fine specimen of the Purple-edged *Trochus* from the N.W. coast of America; rare." [=*T. cælatus*, var. β. Gmel., teste Dillw. vol. ii. p. 800.]

1802, 1803. *Buccinum crispatum.* "The furbelowed Whelk." [=*B. plicatum*, Mart., non Ln.]

1841, 1842. *Murex amplustre.* N.W. coast of America. [This erroneous locality is copied from the Portland Cat.. The species is quoted from *Buccinum* (*Latirus*) *aplustre*, Mart., no. 3. pl. 1. f. 3, where it is rightly assigned to the Friendly Is. =*M. argus*, var. γ. Gmel., teste Dillw. vol. ii. p. 735.]

The assignment of West American species to New Zealand, begun by Martyn, has continued a source of error to the present time. It occurs in Dr. Gould's 'Exploring Expedition Mollusca,' in the Cumingian Collection, and in the British Museum.

In the 'Travels in New Zealand,' by Ernest Dieffenbach, M.D., London, 1843, vol. i. pp. 228–264, is given a "Catalogue of the Species of Mollusca and their Shells, which have hitherto been recorded as found at New Zealand," &c., by J. E. Gray. The author premises that some of the species [marked *]

assigned by the older writers may be found erroneously placed. The following are probably from the West coast of North America, with the synonymy as understood by Dr. Gray:—

Page. No.

229 8. *Murex foliatus*, Gmel. 3329. = *M. purpura alata*, Chemn. x. pl. 169. f. 1538–9; Wood's Cat. f. 13. *Purpura foliata*, Mart. U. C. ii. 66.—*Hab.* N. Zealand, *Humphreys*. King George's Sound, *Martyn*. ["= *M. tripterus*, Kien.: non *M. tripterus*, Born et auct. = *trialatus*, Kien." teste Hanl.]

229 9. *Murex lyratus*, Gmel. 3531. = *M. glomus cereus*, Chem. x. pl. 169. f. 1634. —*Buccinum lyratum*, Martyn, U. C. ii. f. 43.—*Hab.* N. Zealand, King George's Bay, *Martyn*.

233 43. *Purpura lamellosa*, = *Buccinum l.*, Gmel., Wood's Cat. f. 60. = *Buc. plicatum*, Martyn, U. C. ii. f. 41. = *Buc. compositum*, Chemn. x. 179, vign. 21. f. A, B. = *Buc. crispatum*, Chemn. xi. 84, pl. 187. f. 1802–3. *Murex cr.*, Lam. 174.—*Hab.* N. Zealand, King George's Sound, *Chemn.*, *Martyn*. Coast of Columbia.

237 *71. *Ziziphinus canaliculatus*. *Trochus c.*, Martyn, U. C. pl. 32, = *Tr. doliarius*, Chemn. x. f. 1579–80; Wood's Cat. f. 96.—*Hab.* N. Zealand, *Martyn*. California, *Capt. Belcher, R.N.*

*72. *Ziziphinus annulatus*. *Trochus a.*, Martyn, U. C. pl. 33. = *T. virgineus*, Chemn. x. f. 1581–2; Wood's Cat. f. 98. = *Tr. cælatus*, β., Gmel.—*Hab.* N. Zealand, *Martyn*. California, *Capt. Belcher*.

243 113. *Bulla Quoyii*, Gray, n. s. = *B. striata*, Q. & G., Voy. Astr. ii. 354, pl. 26. f. 8, 9, non Lam.—*Hab.* N. Zealand, *Quoy*, *Stanger*.

But the first authentic information on the molluscs of the North-western coast is given in the 'Voyage Round the World, but more particularly to the N.W. Coast of America,' by Capt. George Dixon, London, 1789: to which is added a Natural History Appendix.

Page 355, fig. 2. *Solen patulus**. Cook's River. [= *Machæra Nuttalli*, Conr.]

In the 'Conchology, or Natural History of Shells,' by George Perry, London, 1811, a work of no little pretension, yet singularly inaccurate, are figured the following species, but without authorities for the assigned localities:—

* As this extract is probably the first description on record of molluscs from the Pacific shores of N. America, by the original collector, and as the book is rarely to be met with, it may be interesting to quote the passage:—

"At the mouth of Cook's River [lat. 59°–61°] are many species of shell-fish, most of them, I presume, nondescript; and of all which I should have endeavoured to have got specimens, had business permitted. Among the bivalves we noticed some of a large species, of the *Cardium* or cockle-genus [*Cardium corbis*, Mart.], half-a-dozen of which would have afforded a good supper for one person; but, for a repast of that kind, our men preferred a large species of the *Solen* genus, which they got in quantity, and were easily discovered by their spouting up the water as the men walked over the sands where they inhabited: as I suppose it to be a new kind, I have given a figure of it in the annexed plate [*Solen patulus*; accurate external and internal views, size of life]. 'Tis a thin brittle shell, smooth within and without: one valve is furnished with two front and two lateral teeth [the 'laterals' are the nymphæ for the ligament]; the other has one front and one side tooth, which slip in between the others in the opposite valve: from the teeth, in each valve, proceeds a strong rib, which extends to above halfway across the shell, and gradually loses itself towards the edge, which is smooth and sharp. The colour of the outside is white, circularly, but faintly, zoned with violet, and is covered with a smooth yellowish-brown epidermis, which appears darkest where the zones are: the inside is white, slightly zoned, and tinted with violet and pink. The animal, as in all species of this genus, protrudes beyond the ends of the shell very much, and is exceeding good food.—A fine specimen of this kind is in the Collection of John Swainson, Esq., of the Custom House, London.—We saw also, on this coast, a kind of muscle, in colour and shape much like the common eatable muscle of Europe, but differed in being circularly wrinkled, and a great deal larger [*Mytilus Californianus*, Conr.]. One valve I saw at Queen Charlotte's Islands measured above nine inches and a half in length.—With pieces of these muscles, sharpened to an exquisite edge and point, the Indians head their harpoons and other instruments for fishing. They fasten them on with a kind of resinous substance."—*Dixon's 'Voyage.'*

Pl. Fig.
9 4. *Polyplex gracilis* [=*Trophon multicostatus*, Esch.]. N. Zealand.
29 5. *Melania striata*. New California. [All the figures of '*Melania*' on this plate represent large *Bulimi*, perhaps from S. America.]
35 4. *Cerithium reticulatum*. New California.
44 2. *Haustrum pictum* [=*Purpura planospira*]. East Indies.
44 3. *Haustrum dentex* [=*P. columellaris*]. Nootka Sound: only 2 sp. known.
44 4. *Haustrum tuberculatum* [=*P. patula*, jun.]. ?—
41 3. *Oliva Leveriana* [=*O. porphyria*]. ?—
47 2. *Trochus decarinatus* [=*Calliostoma canaliculatum*]. N. Zealand.
58 2. *Venus radiata* [=*Callista lupinaria*]. N. Zealand.

The common Californian *Haliotis* was, it seems, first described in the 'Zoological Miscellany,' by Dr. W. E. Leach, vol. i. 1814*.

Page 131, pl. 58. *Haliotis Cracherodii*, Leach. California.

Solander made use of the materials he had collected in Cook's Voyage, in compiling a work on Conchology of considerable merit. Dillwyn made a copy of it, and used it in preparing his own, allowing priority to its specific names; but it was never published. The types were lately parted-with by the Linnean Society, who had determined not to keep any collections except those of Linnæus. The 'Descriptive Catalogue of Recent Shells,' &c., by L. W. Dillwyn: London, 1817, is considered by Dr. Gray to be the best conchological work arranged according to the old system. The following are quoted from the West Coast:—

Vol. Page.
i. 301. *Mytilus frons*, Linn.=*Ostrea frons*, Sol. Callone. Acapulco, *Humphreys*; West Indies, *auct.*
i. 469. *Cypræa pustulata*, Sol. Acapulco.
ii. 617. *Buccinum plumbeum*, Chemn. California. [*Monoceros*, ?S. America.]

Following Dillwyn, and nearly eclipsing his fame through the originality and excellence of his classification, appeared Lamarck's 'Animaux sans Vertèbres,' 1818–1822. Coordinate with or preceding this work are his Articles in the 'Annales du Muséum' and the 'Encyclopédie.' The fresh sources of his information are quoted in the first Report, p. 169.

In Delessert's 'Recueil,' 1841, are figured

Pl. 2, fig. 1. *Solen ambiguus*, Lam. [=*S. rudis*, C. B. Ad.] "Les mers d'Amérique."
Pl. 19, fig. 2. *Cytherea semilamellosa*, Gaudichaud [=*C. lupinaria*]. China Seas.

In Deshayes' invaluable edition of the 'An. s. Vert.,' Paris, 1835–45, are quoted a variety of West Coast species which have already appeared under their original authorities. The following may be added:—

Vol. Page.
viii. 232. *Bulimus Mexicanus*, Lam.=*Helix vittata*, Fér. Mexico.
ix. 33. *Haliotis Californiensis*, Swains.=*H. glabra*, Desh. California.
ix. 357. *Pleurotoma tuberculifera*, Br. & Sby. California.
ix. 584. *Murex radix*, Gmel.=*M. melanomathos* (pars), Dillw. Acapulco.
ix. 605. *Murex foliatus*, Gmel.=*M. tripterus*, Kien. N.W. America. "? India."

The last of the early writers whose works should here be quoted, and whose ideas on the relations of genera were considerably in advance of the age, though somewhat fanciful, is Swainson, in his 'Zoological Illustrations,' 1820–1833; 'Appendix to the Sale Catalogue of Mrs. Bligh's Shells,' 1822; and 'Exotic Conchology,' 1821–1835, reissued by Hanley, 1841. These works contain the following West Coast species:—

* This work has been translated into French, and republished, by Chenu; where the same species is found on page 8, pl. 3. f. 2.

Bligh Cat. Page.

2. *Haliotis rufescens*, Swains. (Ditto in Exot. Conch. ed. ii. p. 34.) Galapagos [?] and California.
4. *Cassis* [*Malea*] *ringens*, Swains. ?—
5. *Cassis corrugata*, Swains. Native of the Galapagos.
5. *Harpa crenata*, Swains. ?—
8. *Strombus granulatus*, Swains. ?—

Exot. Conch. Plate.

86. *Conus princeps*, Ln. = *C. regius*, Martini, Lam. (C. P. var. β., Ln. = *C. ebræus*.) Asiatic Ocean.
97 (middle figure). *Marginella prunum*, Gmel., Martini = *Voluta plumbea*, Sol. MS. Africa. [The pinched W. Indian form.]
182. *Cypræa spadicea*, Swains., Tilloch's Phil. Mag. vol. lxi. p. 376. South Seas (*Mawe*).
80. *Haliotis Californiensis*, Swains. [Figured with 9 small holes.] 1821.
55. *Solen ambiguus*, Lam. N. America, 1820. [This shell is conspecific with the "*S. medius*, Alashka," of the B. M. Coll.; differing somewhat from the *S. ambiguus* as figured by Delessert. The B. M. locality is perhaps erroneous.]

24. *Valenciennes' Memoir on Humb. and Bonpl.*, 1833.—The following notes are from a study of the complete copy in the Libr. Roy. Coll. Surgeons.

Page.

221. *Donax radiata* [=var. of *D. punctatostriatus*, Hanl. 1843].
219. *Venus succincta* [= *Chione Californiensis*, Brod. 1835].
245. *Bulimus undatus*. [The Caribbean, not the Mexican, type is here figured.]
267. *Haliotis Californiana* [= *H. rufescens*, Swains., not *H. Californiensis*, Swains.].
267. (Add) *Haliotis interrupta*, Val. Tropical America. [The description accords with the young of *H. Cracherodii*, Leach.]
277. *Cerithium musica*. [Description accords with *C. maculosum*, Kien.]
278. *Cerithium granosum* [= *Cerithidea varicosa*].
279. *Cerithium fragaria* [= *Rhinoclavis gemmata*, Hds.].
282. *Cerithium varicosum* [= *Cerithidea varicosa*, Sby.].
308. *Strombus cancellatus*. Closely resembles *Rostellaria fissurella*, from Grignon. [Probably E. Indian.]
338. *Conus scalaris* [= *C. gradatus* (Mawe), Wood's Suppl.].
270. *Solarium bicanaliculatum*. Small species, like *S. Herberti*, Desh. Enc.
265. *Natica Bonplandi*. [The figure exactly represents *Neverita patula*, Sby.]
266. (Add) *Natica uber*, Val. Cumana.
317. *Purpura semi-imbricata*, Lam. [An. s. Vert. vol. x. p. 84, no. 39; not since identified from the brief description. Perhaps = *Cuma costata*, Blainv.]
287. *Fusus turris* [= *F. Dupetithouarsii*, Kien.].
290. *Fusus Magellanicus* " = *Buc. Geversianum*, Pallas, = *Murex Peruvianus*, Enc. Méth."
295. *Ficula ficoides* [? = *decussata*].
296. *Pyrula spirata* [? = *Rapa*, jun.].

25. *Coquille*.—All the limpets quoted are South American.

26. *Eschscholtz*.—The following observations may be useful to the student:

Page.

10. *Murex ferrugineus* [= *Purp. crispata*, Chemn., var.; varices few, scarcely frilled].
11. *Murex lactuca* [= *Purpura crispata*, Chemn.].
11. *Murex multicostatus* [is not *Trophon clathratus*, as supposed by Midd.; but probably = *T. Gunneri*. It resembles *T. laciniatum*, Mart. (Falkland Is.) on a small scale; varices coronated, without spiral sculpture].
16. *Acmæa*. [Genus described in the Appendix to Kotzebue's Second Voyage, 1830, p. 350; somewhat before *Tectura*, teste Woodward.]
18. *Acmæa mamillata*. [The 'crowded tubercles' were perhaps due to nullipore.]
19. *Acmæa cassis* [if a northern shell, is perhaps the strongly ribbed var. of *pelta*; but the figure accords best with the Cape Horn species, *P. ænea*, Mart.].
20. *Acmæa digitalis* [is perhaps distinct from the variable *persona*; but passes into it by easy transitions].

Page.
21. *Fissurella aspera* [= *Glyphis Lincolni*, Gray, = *cratitia*, Gld. But *Gl. densiclathrata*, Rve, is probably distinct; Sta Barbara, *Jewett*, *Cooper*].

27. *Tankerville Cat.*, 1825.—The following species are also from the West Coast. The prices are added from the British Museum copy, as a record of their former rarity:—

No.	App. page.	Price.	
70		10*s.*	*Solen ambiguus.*
161		15*s.*	*Tellina operculata.*
162		5*s.*	*Tellina punicea.*
206		£10 10*s.*	*Lucina Childreni* [described by Gray in Ann. Phil. 1824; v. also Zool. Journ. vol. i. 1825, pp. 221–2. There is no authority for the statement that it came from Brazil. The Br. Mus. specimens are from "Mus. Cracherode," and are probably West Coast. The only known locality is Cape St. Lucas.]
1293		30*s.*	*Trochus annulatus.*
1294		20*s.*	*Trochus doliarius.*
1690		10*s.*	*Murex crispatus.*
1842		15*s.*	*Purpura patula.*
1855		20*s.*	*Purpura planospira.*
1896		45*s.*	*Harpa crenata.*
2240		15*s.*	*Cypræa spadicea.*
2251		2*s.*	*Cypræa albuginosa.*
2330	xxxii	15*s.*	*Oliva splendidula.* *Hab.* ?—
2332	xxxiii	2*s.* 6*d.*	*Oliva biplicata.* West Coast North America.
2333	xxxiv	2*s.*	*Oliva columellaris.* ?—
2347		£5 5*s.*	*Conus regius.*

The „ in Rep., p. 174, should have been omitted, except at no. 808, p. vi. No. 1401 is described, on p. xii, as from Newfoundland. No. 1786 should have no page-reference.

In the 'Zoological Journal,' London, 1824–1829, appear descriptions of the following species:—

		Page.	
Vol. i.	March 1824,	60.	*Natica patula*, Sby. "Brought from S. America by M. de Humboldt. 2 specimens only known."*
„	Oct. 1824,	369.	*Cypræa subrostrata*, Gray. Nehoue (Mus. Sby.). ['Probably fossil' (*Gray*): a white, smooth species, not to be confounded with *Trivia subrostrata.*]
„	Jan. 1825,	510.	*Cypræa albuginosa*, Mawe, pl. 7. f. 2; pl. 12. f. 2. California. Named, without description, in Mawe's Cat. (= *C. poraria*, var., Ducl.: Z. J. iv. p. 68.)
		513.	*Cypræa pustulata*, Sol. S. Coast of Mexico. China.
Vol. iii.	Jan. 1827,	70.	*Hinnites giganteus* (Sby.). ?— [= *H. Poulsoni*, Conr. Calif.] = *Hinnita gigantea*, Gray, Ann. Phil. Aug. 1826. = *Lima gigantea*, Id. in loc. cit. [non J. Sby.]
„	Sept. 1827,	363.	*Cypræa subrostrata*, Gray [bis, Trivia]. ?—
		364.	*Cypræa radians*, Lam. = *C. oniscus*, Dillw. = *C. pediculus*, β., Gmel. + *C. costata*, Dillw. W. Coast of Mexico, ? Adriatic.
		365.	*Cypræa Californiana*, Gray [Trivia]. California.
Vol. iv.	Jan. 1828,	145–162.	Monograph of *Ovulum*, by G. B. Sowerby, containing the species afterwards figured in the Spec. Conch.

28. *Beechey's Voyage.*—Increased study has supplied the following corrections:—

* At p. 511, note *, Dr. Gray states that the *Natica patula*, Barnes, Ann. Lyc. Nat. Hist. N. Y., Sept. 1824, i. 133, is "the shell described under that name by Sby. As there is another *N. patula* [? ubi], must be called by Mr. Barnes's MS. name of *N. helicoides*." Also that *Dolium dentatum*, Barnes, loc. cit. = *D. ringens*, Sby.

Page.
Z. J. 372. *Natica pallida* [=*Lunatia caurina*, Gld.,+*soluta*, Gld.].
372. *Natica otis.* [Var.=*Polinices fusca*, Cpr.]
372. *Natica clausa* [=*N. Beverlii*, Leach, MS. in B. M.].
378. *Fusus lapillus*=*Buc. subrostratum*, Gray. [Resembles the smooth, stumpy form of *Purpura plicata*, Mart.: "perfectly distinct," teste Hanl.]
379. *Conus arcuatus* [as figured in Z. B. V., is a very different shell from that in Mus. Cum. and the monographs; the latter is allied to *C. tornatus*].
379. *Conus interruptus* [resembles the broad form of *C. mahogani*].
Z. B. V. 130. (Add) *Oliva semistriata*, Gray, pl. 36. f. 10. *Hab.* ?—[Panama, &c.]
119. *Conus Ximenes* [scarcely differs from *C. mahogani*, var. in Mus. Cum.].
132. [Should be] *Agaronia* [et passim].
147. (Add) *Mouretia Peruviana*, Sby. (P. Z. S. 1835, p. 6) pl. 39. f. 6, 6′. [Also Margarita Bay, teste *Pease*.]
148. *Patella Mazatlandica.* [This is the Sandwich Islands species, =*P. exarata*, Nutt., teste Hanl. The large specimens quoted are probably *P. talcosa*, Gld.]
150. *Chama echinata.* [Further series of specimens make it doubtful whether this be not a distinct species from *C. frondosa*, var. The original sculpture has not yet been detected.]
151. [Should be] *Cytherea biradiata.*
152. (Add) *Cardita borealis*, Conr. (=*"Arcturus rudis*, Humphr.") pl. 44. f. 1. [Probably from near Icy Cape. Mus. Belcher.]

The types of the species described from this important voyage have been scattered. Some have been identified from Admiral Sir E. Belcher's Collection, which he kindly allowed me to examine for that purpose; others are in the possession of Mr. Hanley; but many appear hopelessly lost.

29. *Wood's Ind. Test.*—In Hanley's Revised Edition of this important work (London, 1856), several new localities are added from the writer's varied experience, and the synonymy is most carefully elaborated. No other book contains such a mass of trustworthy information on the old species in so small a compass. The following are quoted, either as original authorities, or for locality or synonymy:—

Page. Fig.
2 10. *Chiton tunicatus*, Wood, Gen. Conch. 1815, pl. 2. f. 1 [=*Katherina Douglasiæ*, Gray]. Sitka.
3 18. *Chiton lineatus*, Wood, Gen. Conch. 1815, pl. 2. f. 4, 5. Sitcha, North Calif. [Mr. Hanley believes that Sitka is the island in lat. 58°, and that Sitcha is in the district now known as Washington Territory, olim Oregon.]
3 20. *Chiton sulcatus*, Wood, Gen. Conch. 1815, pl. 3. f. 1. Galapagos.
19 16. *Solen maximus*, Wood, Gen. Conch. 1815, pl. 31. f. 3 [=*S. patulus*, Dixon. N.W. America]. Sandw. Is.
21 8. *Tellina rugosa*, Born. Is. of Opara, New California. [Pacific Is.]
27 73. *Tellina muricata*, Chemn.=*Lucina scabra*, Rve. Mexico.
82 97. *Conus pusillus*, Wood: non Chemn. nec Lam. [nec Gld.] = *C. puncticulatus*, var., Lam. (quasi Brug.) Mexico.
88 31. *Cypræa onyx*, Gray (quasi Lin.) = *C. adusta*, Chemn. [Pacific Is. The San Diegan shell is closely allied, =*Luponia spadicea*.] 'Calif.'
99 35. *Voluta incrassata*, Dillw.; posterior to *O. angulata*, Lam. Centr. Am.
183 14. *Haliotis Cracherodii*, Leach=*H. glabra*, Schub. 1829, non Chemn. et auct. Calif.
Suppl. 201 3. *Tellina lutea*, Gray=*T. alternidentata*, Br. & Sby.=*T. Guilfordiæ*, Gray, in Griff. Cuv. pl. 19. f. 2. Icy Cape.
202 1. *Donax scalpellum*, Gray, Ann. Phil. 1825, ix. 166; =*D. elongata*, Mawe, Conch. pl. 9. f. 6, 1823. Calif.

	Page.	Fig.	
Suppl.	202	2.	*Donax stultorum*, Mawe, l. c. pl. 9. f. 7; = *Trigona st.*, Gray, Analyst, 1838. ? S. America [= *Tr. crassatelloides*, jun. Calif.].
	204	5.	*Chama crassicostata* = *Venericardia c.*, Sby., Tank. Cat. p. 4. = *Cardita Cuvieri*, Brod., P. Z. S. 1832. = *C. Michelini*, Val. Acapulco.
	205	11.	*Arca pectiniformis*, Gray (*Pectunculus*), non Lam. = *P. inæqualis*, Sby.
	208	6.	*Conus gradatus*, Mawe. Calif. [= *C. scalaris*, Val.] Pan.
	211	25.	*Voluta lens*, Mawe. Pan.
	211	26.	*Voluta harpa*, Mawe, Conch. Front. f. 2. 1823; = *V. nucleus*, Lam. S. Pacific.
	211	33.	*Voluta nux*, B.M. = *Oliva biplicata*, Sby., Tank. Cat. Calif.
	212	38.	*Voluta tenebrosa*, Mawe = *O. undatella*, Ducl. (Lam.) Pan.
	212	4.	*Buccinum tenue*, Mawe = *Cassis Massenæ*, Kien. Galapagos.
	212	7.	*Buccinum distortum*, Swains., Bligh's Cat. = *Columbella triumphalis*, Ducl. [*Clavella*]. W. Columbia.
	213	10.	*Buccinum brevidentatum*, Mawe = *Purp. cornigera*, Blainv. = *P. ocellata*, Kien. W. Columbia.
	213	11.	*Buccinum denticulatum*, Mawe } = *Monoceros lugubre*, Sby. Gen.
	213	12.	*Buccinum armatum*, Mawe } Calif.
	213	13.	*Buccinum tectum*, Mawe = *Purp. callosa*, Sby. Gen., non Lam. = *P. angulifera*, Kien. (Ducl.) = *Cuma sulcata*, Swains. Mal. Pan.
	213	15.	*Buccinum planaxis*, Mawe = *Pl. planicosta*, Sby. = *P. canaliculata*, Duval, Rev. Zool. 1840, p. 107. Pan. [*Purp. canaliculata*, Ducl., is quite distinct.]
	214	25.	*Buccinum elongatum*, Mawe = *Terebra strigata*, Sby., Tank. Cat. = *T. zebra*, Kien. Pan.
	215	15.	*Strombus bituberculatus*, B.M., non auct. = *Str. Peruvianus*, Swains., Phil. Mag. 62. W. Columb.
	216	3.	*Murex rigidus*, B.M. = *Buc. nodatum*, Martyn = *Murex n.*, Gmel., Dillw. = *Turbinella rigida*, Gray. Pan. [Probably the Pacific sp.]
	217	10.	*Murex sanguineus*, Mawe = *Turbinella varicosa*, Rve. Galapagos.
	217	14.	*Murex salmo*, Mawe = *Fasciolaria granosa*, Kien., as of Brod., P. Z. S. 1832. Panama.
	218	1.	*Trochus undosus*, Wood = *T. undatus*, Mawe, Conch. no. 146 (not described); = *T. balænarum*, Val. Calif.
	219	4.	*Trochus pellis-serpentis*, Mawe = *Tegula elegans*, Less., Ill. Zool. pl. 50; = *Tr. strigilatus*, Phil. (quasi Anton) Abbild. pl. 2. f. 9. Pan.
	225	45.	*Turbo saxosus*, Mawe = *Marmorostoma undulata*, Swains., Zool. Ill. s. 2. Pan.
	233	6.	*Haliotis corrugata*, Mawe, Conch. no. 181. ? = *H. nodosa*, Phil. Abbil. pl. 2. Calif.
	233	3.	*Patella peziza*, Gray = *Dispotæa Byronensis*, Gray, Enc. Metr. Moll. pl. 4. f. 4 = [? *Crucibulum spinosum*, var.]. Chili.

31. *Voy. Beagle.*—The *Triton scaber* is rightly assigned to S. America: there is no satisfactory evidence for its appearance on the N.W. coast. The shells so quoted are probably either imported from the Magellan district, or are *Priene Oregonensis*, jun., or *Ocinebra*, var. *aspera*.

36. *Duclos.*—The original article is in the 'Annales Nat. Sc.,' May 1832, and contains the following species:—

Page.	Plate.	Fig.	
104	1	1.	*Purpura canaliculata*, Ducl., resembles *P. succincta* on a small scale. Cal.; very rare. [Figured with 10 principal and a few intercalary ribs. = *P. decemcostata*, Midd.]
105	1	2.	*Purpura melones*, Ducl. ?— [Panama.]
109	2	8.	*Purpura centiquadra*, Val. MS. [Ducl. states that Val. altered his own name to *speciosa* while the sheet was passing through the press. The latter, however, bears date 1833.]
111	2	10.	*Purpura sphæridia*, Ducl. Cal. [A well-known *Sistrum* from the Pacific Is.]

The species quoted in the text from Guérin, which appear in the Mag. Zool. for 1844, also appear here with the early date. *Oliva polpaster*, a southern form, from Guayaquil, &c., is distinct from all varieties of the Gulf species, *O. Cumingii*; it bears date 1839. In the same vol. are described and figured—

Plate.

2. *Calyptræa* (*Calypeopsis*) *rugosa*, Less. Payta, Peru. [= *Cruc. imbricatum*, without pits.]
23. *Conus hieroglyphus*, Ducl. Probably Cal. [A Pacific form, like *C. abbreviatus*.]
27. *Cypræa eglantina*, Ducl. Cal. [A starved var. of *Aricia arabica*, Pacific Is.]

38. *Lady Douglas* (afterwards known as Lady Wigram).—*Placunanomia cepio*. [The type is an old shell, with faint ribs.]

Placunanomia alope. [The type is a young shell, with small scars and faint ribs. The large series of specimens examined in the Smithsonian collections proves that these forms are among the many varieties of *P. macroschisma*. The Indians have a superstitious dread of handling it. Many more species have since been detected in the Brit. Mus., from the late Lady Wigram's valuable donations, including *Macoma inquinata*, Desh., described from her specimens; but, as they are evidently from mixed localities, it has not been thought necessary to catalogue them.]

39. *Nuttall*.—The verification of Conrad's species being of considerable importance, I made diligent search for the original types during a recent tour in the United States. The supposed collection at Harvard University, Cambridge, Mass., has not been discovered by Professor Agassiz. The inquiries which Professor Longfellow kindly made at my request resulted in information that it was "in Dr. Wyman's Mus. Nat. Hist., in the granite building on Howard Street;" but no opportunity has been afforded of collating it, or even of verifying its existence. Dr. Jay rendered me every assistance in studying the types which he has catalogued in his collection, now rearranging in his residence at Memironeck, near New York, and gave such duplicates as could be spared for the Smithsonian Museum. Several species, however, were not to be found, and some were clearly erroneous, as e. g. *Chama* "*exogyra*, Conr.," which proved to be *C. lobata*, Brod.; W. I., teste Cuming; China, Brit. Mus. The most satisfactory information was derived from an interview with Mr. Conrad himself at the Acad. Nat. Sci., Philadelphia, where the honorary curator, Mr. W. G. Binney, afforded us all possible aid in eliminating types from the collections of the Academy and of private conchologists in the city. Mr. Nuttall's death (the news of which was received soon after) prevented his revising the corrections thus obtained. As he had previously presented a duplicate series of his shells to the Brit. Mus., which had been incorporated with the general collection, and had signified to me his intention to leave the unique specimens to the nation, I at once communicated with the survivors and with Dr. Gray, who was fortunate enough to stop the intended sale, and to secure the shells, which were kindly presented by the executors. They are now mounted, and kept in drawers adjoining the Reigen collection, the Vancouver collection, and the Stimpsonian typical collection of East Coast N. American shells. The following is a *résumé* of corrections obtained from these different sources, numbered to correspond with the list, Rep. pp. 194–201:—

2. "*Parapholas*" *penita* [is a *Pholadidea*].
3. *Platyodon cancellatus* [= *Cryptodonta myoides*, Nutt. MS.].
4. *Cryptodon Nuttallii*, Conr. [The author, finding the generic name preoccupied, changed it to *Schizothærus* N.: 1852, teste Bin. Bibl.; 1854, Journ. A. N. S. Phil. p. 199, = *Lutraria capax*, Gld, = *L. maxima*, Midd., = *Tresus maximus*,

Gray. Mr. Nuttall only brought home young specimens of this extraordinary shell. In its adult state it assumes either a transverse form (=*capax*) or the elongated condition, redescribed in a fossil state as new. Between these there is every gradation, as can be traced in the magnificent series in the Smiths. Mus.; and a caskful of the animals in spirits, of various ages, has affiliated the large shells to the original Nuttallian specimens.]

10. *Pandora punctata* [is a *Clidiophora*. The series so named in the Nuttallian collection belongs, however, to the Atlantic *Cl. trilineata*].

11. *Solecurtus lucidus* [is almost certainly the young of no. 12. The amount of obliquity in the internal rib is extremely variable in the adult specimens].

12. *Solecurtus Nuttallii* [=*Machæra patula*, Dixon,=*Aulus grandis*, Gmel., teste Hds. in Mus. Cum. Mr. C.'s "*grandis*, var.," from Monterey, suits in its proportions for the adult of *S. lucidus*. The shell has been widely distributed by commerce, and appears to extend far in a northerly direction. The animal is very beautifully fringed].

14. *Solecurtus Californianus* [=*S. Dombeyi*, teste Mus. Cuming: non Hanl. MS.].

15. *Psammobia Pacifica* [is a *Heterodonax*, probably identical with the W. Indian *H. bimaculata*, which is found abundantly in its many varieties at Acapulco;=*Tellina vicina*, C. B. Ad.].

17. *Sanguinolaria Californiana* [=*Macoma inconspicua*, Brod. & Sby., and is a northern species].

18. *Sanguinolaria rubroradiata* [is the young of a large species of *Psammobia*].

22. *Tellina alta* [=(from types) ?*Scrobicularia biangulata*, Cpr.].

23. [=*Macoma edulis*, Nutt.; a northern variety of *M. secta*, no. 25, and quite distinct from *M. edentula*.]

26. The locality is not confirmed, and is probably erroneous.

27. [Dr. Gould considers his *D. obesus* a distinct species; from a large series, it appears identical.]

28, 29. [These species of *Standella*, described from young specimens, were found of very large size by Dr. Cooper, with what may prove a third species, perhaps *S. nasuta*, Gld., *olim*.]

30*b*. *Petricola carditoides* [with *P. arcuata*+*cylindracea*, Desh., are varieties of *P. Californica*. The series preserved in the Smithsonian Museum connects all the extreme forms].

32. *Mysia tumida*, Conr. MS. [=*Diplodonta orbella*, Gld., and belongs to the section *Sphærella*, Conr. The label had been assigned by accident to a young valve of a *Chione*, probably from the Sandwich Is.].

33. *Tapes staminea*. [This is the extreme southern form of a widely diffused and very variable species, of which the normal condition is *Saxidomus Petitii*, Desh.,=*Venus rigida*, Gld. *pars*. The principal varieties have been named *Tapes diversa*, Sby.=*Venus mundulus*, Rve., and *Venus ruderata*, Desh.]

34. [The Californian *Saxidomi* divide themselves into three groups: the large, southern, oval, grooved shells=*S. aratus*, Gld.; the subquadrate, comparatively smooth, northern shells=*S. squalidus*+*giganteus*, Desh.; and an intermediate form, which is the true *S. Nuttallii*, Conr. Some of Mr. Nuttall's specimens were, however, the young of *S. aratus*, of which the adult was not known till very recently.]

35. [The young of this *Pachydesma* is "*Trigona stultorum*, Gray," Desh. MS. in British Museum.]

36. *Cytherea callosa* [=*C. nobilis*, Rve. It is not a *Dosinia*, but the type of a new subgenus, *Amiantis*, differing from *Callista* as *Mercenaria* does from *Venus*].

37. Plate 19, fig. 16 (not 14 nor 15). [The true *Venus Nuttallii* of Conr. (teste Conr. ips. and types in Mus. Phil. Ac. and Jay) is not the shell here catalogued, which generally goes by that name, but is a synonym for the *V. Californiensis*, Brod.,=*succincta*, Val. The error was corrected in the Mus. Cum. in time for the right shell to be figured by Reeve in his recent monograph. It is doubtful what name Conrad intended for the shell here catalogued, which belongs to the group of *Stutchburyi*, *fluctifraga*, &c. If really distinct from the latter, it may stand as *Chione callosa*, Sby. jun. (non Conr.)]

38. *Venus Californiana* [(teste Conr. ips.) was intended for *V. Californiensis*, Brod. Not having access to the type, it could hardly be recognized by the

brief diagnosis. The name should therefore be dropped. The shell, pl. 19. fig. 15 (not 16) = *Chione simillima*, Sby., no. 39; a good, Lower Californian species. It seems that the error was not in the numbering of the figures, as Mr. Nuttall supposed, but in Conrad's identification of Broderip's species].

40. *Chione excavata* [is closely related to *Ch. succincta*; the unique type, however, in Brit. Mus. displays characteristic differences of sculpture. It is singularly like the W. Indian *Ch. cancellata*, and may prove exotic].

41. *Cypricardia Californica* [= *C. Guiniaca*, Lam., = *C. Duperryi*, Desh. Almost certainly from the Sandwich Is.].

45, 45*b*. *Cardium Californianum* [= *C. Nuttallii*, var. The species is named "*C. corbis*, Mart.," by Desh. MS. in Mus. Brit. and Cuming].

46. *Cardium quadragenarium* [= *C. luteolabrum*, Gld.].

51. *v. anteà*, no. 32.

56. *Modiola recta*. [Described from very young specimens. The broad form is *M. flabellata*, Gld.]

59. *Mytilus bifurcatus*. [The type is lost; the figure and description would suit many species. It is allocated, in Mus. Cum., to the Californian *Septifer*; but by Pease to a Sandwich Island *Mytilus*.]

60. [None of Conrad's species of *Isognomon* have been confirmed as from California. They are known to inhabit the Pacific Islands.]

62*b*. [Mr. Nuttall also brought an oyster, which he named in MS. *O. latecaudata*, = *O. lurida*, var.; and *Hinnites giganteus*, Gray, = *H. Poulsoni*, Conr.]

64. [Dr. Gould states that *H. Nickliniana*, Lea, = *H. Californiensis*, Pfr., Chemn., Rve.; but that *H. Californiensis*, Lea, is distinct.]

69. *Helix Townsendiana* [= *H. æruginosa*, Gld. MS.].

74. *Chiton Nuttallii* [is an *Ischnochiton*].

75. *Chiton acutus* [is an aberrant form of *Mopalia*. "*Chiton consimilis*," Nutt. MS. in Brit. Mus., appears to be *Mopalia Hindsii*, var. "*Chiton Californicus*" Nutt. MS., = "*Acanthopleura*" *scabra*, Rve.].

77. *Patella mamillata*, Nutt. [(non Esch.) is now assigned in Mus. Cuming to *Acmæa scabra*, Nutt., var. *limatula*].

83. *Fissurella ornata*, Nutt. [= *F. volcano*, Rve.].

84. *Glyphis densiclathrata*, Rve. [*V. anteà*, p. 522. The shell has been lost.]

86. *H. Californiensis*, Swains. [(not *Californiana*, Val., = *rufescens*), is an extreme var. of *H. Cracherodii*. The series in the Smithsonian Mus. have 5, 6, 7, 8, and 9 holes; as soon as it has 10 and 11, it passes into *Californiensis*, which was figured in 1821 with 9 holes. When these are numerous, they are generally small in proportion].

91. *Calliostoma doliarium* [= *C. canaliculatum*, Mart. This and *C. annulatum*, Mart., are quite distinct from *C. filosum*, which = *C. costatum*, Mart.].

92. *Omphalius ater* [is the S. American species. The common Californian shell is]

94. *O. marginatus*, Nutt. MS. [= *funebralis*, A. Ad.].

97*b*. The collection contains one specimen of *Crepidula dorsata*.

103. [Is a *Serpulorbis*, without operc., teste Cooper.]

106. *Litorina tenebrata* [should be *patula*, Gld. (non Jeffr.). Nuttall's MS. name was published by Phil. in 1845].

107. *Natica ? maroccana*, var. *Californica*. [The varietal name must be dropped. The shell certainly came from the Sandwich Islands.]

108. [The shell is *Vitularia salebrosa*, jun., and not] *Ranella triquetra*.

109. *Mitra maura* [Swains., teste Rve. (? ubi) = *M. orientalis*, Gray, = *M.* "*Chilensis*," Kien.].

110. *Olivella glandinaria*, Nutt. [= *O. biplicata*, Sby.].

112, 113. *Purpura aperta* and *P. harpa* [are certainly from the Sandwich Islands].

114. *Purpura emarginata* [was described by Desh. from an immature specimen in which a half-formed knob caused an "emargination." The adult is one very extreme form; *P. ostrina*, Gld., is another; *P. fuscata*, Fbs., is a third. The normal condition is *P. lapillus*, Cooper (non Linn.), = *saxicola*, Val. Mr. Nuttall's collection also contains] *P. crispata*, var.

116. *Monoceros brevidens* [is an accidentally short-toothed form of *M. lapilloides*].

118. *Cerostoma Nuttallii* [with *C. foliatum* and *C. monoceros*, Sby., belongs to *Purpuridæ*].

The specimens numbered 2, 5, 8, 9, 19, 21, 28–31, 36, 44, 46, 49, 50, 52–54, 56, 59, 64–67, 70–72, 76, 84, 86–88, 98, 101, 103, 104, and 109 do not appear in the Brit. Mus. Nuttallian collection.

41. *Voy. Venus.*—Rev. Zool. and Guér. Mag.

Arca trapezia [=*A. tuberculosa*].
Saxicava legumen [=*S. pholadis*; ?from hole of *Lithophagus*].
Petricola arcuata [=the normal state of *P. carditoides*, Conr.].
Petricola cylindracea [=a short form of the same sp., developing ridges of growth, like *Tapes ruderata*, Desh.].
Venerupis gigantea [=*Saxidomus squalidus*, Desh.].
Cypricardia Duperreyi [=*C. Guinaiaca*, Lam., =*C. Californica*, Conr. A Sandwich Island species, twice quoted, but not confirmed, from Cal.].
Cardium Laperoussii [is an *Aphrodite*, like *Grœnlandicum*, but more transverse, and with lateral teeth less developed. This very rare and probably boreal shell has just been identified from Adm. Sir E. Belcher's coll.].
Cardium Californiense, Desh. [is not *C. Californianum* (=*Nuttallii*), Conr.; but=*C. pseudofossile*, Rve., 1844. The name of Desh. is unfortunate, as his shell is the Kamtschatkan form with strong ribs. The Californian form is smaller, with fainter ribs,=*C. blandum*, Gld.].
Purpura Freycinetii [is figured from a very extreme form of the Japanese species. *P. ostrina* passes into similar varieties].
Velutina Mülleri [probably=*V. lævigata*, which reaches Vancouver].
Lucina cristata [=*Tellidora lunulata*, Holmes; described from the Pleistocene of S. Carolina, and lately dredged alive by Dr. Stimpson; not *T. Burneti*].

The following may be added to Deshayes' list:—

Pl. 81. *Tellina ligamentina*, Desh., 1843. *Hab.* ?— [=*Macoma secta*, Conr.]
Tellina Japonica, Desh., in Mus. Cum. [also appears to be *M. secta*, jun.].

In Valenciennes' plates to the Voy. Ven. have been recognized the following West Coast species and synonyms, in addition to those quoted in Rep. pp. 203–204:—

Plate.	Fig.	
3	2.	*Trochus diadematus*, Val. [resembles *Pomaulax undosus*, jun., but the surface is faintly wrinkled all over; umbilical region not chiseled; and operc. not ridged. It is probably intended for *Pachypoma gibberosum*].
4	1.	*Trochus rubiginosus*, Val. [probably=*T. annulatus*, Mart.].
	2.	*Trochus pellucidus*, Val. [resembles *T. lima*, Panama].
6	3.	*Buccinum Prevostii*, Val. [probably=*Pisania pagodus*].
8	1.	*Purpura bufonides*, Val. [appears one of the many vars. of *P. biserialis*].
9	1.	*Purpura rupestris*, Val. [probably=*Monoceros lugubre*, jun.].
10	1.	*Murex aciculiger*, Val. [is represented with labral tooth and closed canal; but resembles *C. festivus*, Hds.].
	3.	*Murex tortuus* (Brod.), Val. [resembles *Ph. princeps*, with a very poor operc., badly drawn].
16	1.	*Venus Thouarsii*, Val. [?=*multicostata*, Sby.; figured with very broad, smooth, close ribs, scarcely indented, except in the middle].
	3.	*Venus pectunculoides*, Val. [is probably *T. grata*, not *histrionica*].
17	2.	*Cardium subelongatum* (Rve.), Val. [appears=*C. procerum*, jun.].
18	2.	*Pecten comatus*, Val. (may be=*hastatus*, jun.; but, although figured without the red spot, it most resembles *Hin. giganteus*, jun.].
19	1.	*Pecten excavatus*, Val. [=*Janira dentata*, Sby.].
	3.	„ *pomatia*, Val. [may be=*P. ventricosus*, jun.].
	4.	„ *rastellinum*, Val. [=*P. hastatus*, jun.].
21		*Ostrea gallus*, Val. ["Acapulco," with large plates,=*O. megodon*, Hanl.].
22	1.	*Cardita arcella*, Val. [?=*Ven. radiata*, Sby.].
	2.	„ *modulosa* (Lam.), Val. [=*Lazaria affinis*].
	3.	„ *turgida* (Lam.), Val. [=*Ven. laticostata*].
	5.	„ *Michelini*, Val. [=*V. Cuvieri*].
23	2.	*Nucula divaricata*, Val. [probably=*N. castrensis*].
24	1.	*Penitella Conradi*, Val. [may be=*Pholadidea ovoidea*].

Plate. Fig.

2. *Penitella xilophaga*, Val. [may be the adult of fig. 4].
3. *Penitel a tubigera*, Val. [may possibly be intended for *Ph. penita*].
4. *Pholas rostrata*, Val. [is probably=*Netastoma Darwinii*, Sby. jun.].
5. *Ungulina luticola*, Val. [may be an extremely bad *Petricola robusta*].
6. *Corbula luticola*, Val. [is probably=*Sphænia fragilis*].
7. *Bornia luticola*, Val. [=*Kellia Laperoussii*].
8. *Saxicava clava*, Val. [=*S. legumen*, Desh.,=*S. pholadis*, var.].

The identification of these species is attended with great uncertainty, as the types have not been seen, and the artist appears to have studied effect rather than accuracy.

42. *Voyage of Sulphur.*—The types of these species appear to have been scattered. Only a part are now to be found in the very valuable collection of Admiral Sir E. Belcher, in which most of the shells are, unfortunately, destitute both of names and of locality-marks.

Murex Belcheri [belongs to Purpuridæ, and may be considered the type of the genus *Chorus*].

Ranella Californica. [After comparing a series with the Cumingian specimens of *R. ventricosa*, it appears that the diagnostic characters are not constant.]

Marginella sapotilla. [The type in Mus. Cuming is much smaller than the ordinary condition of *M. prunum*=*cærulescens*. Lam., to which species the common Panama shells were referred by Mr. Cuming. In his collection, however, they stand thus:—Ordinary Panamic type "*sapotilla*, Hds.: 5–13 fms., sandy mud, Panama, *H.C.*" Another tablet of the true Panama shells "*Marginella*, n. sp., Panama,"—"San Domingo" having been crossed out. The small West Indian form, analogous to the typical *sapotilla*, is given as "*glans*, Mke." The large West Indian shells, with violet tinge behind the labrum, are "*cærulescens*, Lam., Panama," without authority. Another series of the W. Indian type is given as "*cærulescens*, var., Lam., 10 fms., sandy mud, Panama," without authority. Either habitat-errors have crept into the Cumingian labels, or else Mr. Redpath's observation will not hold, viz. that the Atlantic shells have a posterior pinch on the labrum, which is not seen in the Pacific. All the authentic series examined from the two coasts bear out his view. There will be two opinions as to whether this be more than a mere local distinction.]

Solarium quadriceps. [On comparing suites of *S. granulosum* from the Texan coast with series from the Gulf of California, it appeared that on each side of the Peninsula the shells went through similar changes in strength of sculpture, size of umbilicus, number of spiral granules, &c.; nor could any clue be obtained by which the coasts could be separated in a mixed collection. Hinds's shell stands at the furthest extreme of removal from *S. granulatum*.]

43. *U. S. Exploring Expedition.*—The shells of this collection were deposited in the Patent Office in Washington, D.C., where, notwithstanding the great care of Mr. Varden, the curator, they were not a little tampered-with. Dr. Gould laboured under great difficulties in his work of description; he had access only to that part of the collection which happened to be unpacked and exposed to view during the brief period that his professional engagements allowed of his visiting the capital; and his request to be allowed to take doubtful shells to Europe for identification was refused. The materials also were of an unsatisfactory kind, a large proportion of the specimens being much weathered, and many of the locality-marks being manifestly erroneous. If occasional errors have been detected in his great work, they may fairly be set down to causes over which the author had no control. Many of these

have been corrected by Dr. Gould himself, in his 'Otia Conchologica,' Boston, 1862, which contains the various papers in the 'Proceedings of the Boston Soc. of Nat. Hist.,' with an appendix. After the organization of the Smithsonian Institution, all the natural-history collections belonging to the Federal Government were transferred to its keeping, with liberty to exchange duplicates. The shells remained unopened, and the types not accessible, till, at the request of Professor Henry, I undertook the arrangement of the collections. Fortunately, a considerable part of the shells professing to be the figured types of the new species were found together, with the artist's marks corresponding with the plates and figures. The result of the examination, so far as the general collection is concerned, will shortly be prepared for the press; it is sufficient here to tabulate the observations on the N.W. American species, which were, as it happened, the most satisfactorily preserved in the whole series. The following additional particulars include the "Rectifications" in the 'Otia,' the paging of which is continued from the "Expedition Shells" quoted in Rep. p. 209. The quarto volume quoted in p. 210 is distinguished as "E. E. Mollusca." The folio atlas of plates bears date on title 1856, but was not published till 1861, teste Binn. Bibl. vol. i. p. 504. The comparisons of types were made in 1860, from a proof copy.

Otia, Page.

3. *Chiton lignosus*=[*Mopalia*] *Merckii*, Midd., test. Gld. E. E. Moll. [from worn specimens:=*Ch. Montereyensis*, Cpr., from perfect shells.]

230. *Chiton* (*Chætopleura*) *vespertinus*. Perhaps=*Ch. lignosus*, var. [A *Mopalia*, differing slightly in the amount of posterior wave. The fig. in E. E. Moll. is made-up from broken specimens.]

6, 242. *Chiton* (*Onithochiton*) *dentiens*. [The shell sent as type of this species, and all the others seen from the coast, agree in belonging to *Ischnochiton*, and are not dentate, as would be presumed from the figures and diagnosis. As Dr. Gould's toothed *Onithochiton* may hereafter be found, the Smithsonian shells have been named *Isch. pseudodentiens*.]

6, 242. *Chiton* (*Chætopleura*) *muscosus*. [=*Acanthopleura muscosa*, H. & A. Ad. Gen.,=*Ch. ornatus*, Nutt. P. Z. S. 1855, p. 232,+*Mopalia consimilis*, Nutt. MS. in B. M. This beautiful species is a true *Mopalia*.]

230. *Chiton* (*Leptochiton*) *interstinctus*. Resembles *C. Sitchensis*, Midd. [=*Callochiton i.*, H. & A. Ad., Gen. It is a true *Ischnochiton*. The genera of Chitonidæ cannot always be ascertained by external characters alone, as indicated in Messrs. Adams's genera. All the species in the Smithsonian Museum have been dissected.]

7, 242. *Patella* (*Tectura*) *fimbriata*=*P. cinis*, Rve. [=*Acmæa pelta*, Esch.].

9, 242. *Patella* (*Nacella*) *instabilis*. [Varies greatly in proportions.]

9, 242. *Lottia* (*Tectura*) *pintadina*. [The types represent the normal condition of *Acmæa patina*. One variety is *A. cribraria*, Gld. MS. The specimens of *A. mesoleuca* intermixed by Dr. G. in the Mexican War collections were, no doubt, affiliated by an oversight.]

10, 243. *Patella* (*Tectura*) *textilis* is a var. of *T. persona*, Esch. [A well-marked form of delicate growth, passing from *A. persona* into *A. pelta*, var.; from the young of which some specimens can hardly be distinguished, except by the fretted pattern.]

10, 243. *Patella* (*Tectura*) *scabra*=*spectrum* (Nutt.), Rve., not *scabra* (Nutt.), Rve. [The type-specimens belong to two species, f. 456, 456*a*, being *A. spectrum*, Nutt., while 456*b* represents the flattened variety of *A. persona*, Esch. (approaching the form *digitalis*, Esch.). As the diagnosis best accords with the latter shell, *P. scabra*, Gld., may stand as a synonym of *persona*, var.; the intermixed specimen, accidentally figured as belonging to the species, being removed to *spectrum*, Nutt. Thus the name *scabra*, not being needed as first described, will remain for Nuttall's species, described by Rve., but first named in print by Jay.]

Otia, Page.
15. *Crepidula lingulata.* [Described from a worn specimen. Perfect shells cannot be separated from *C. bilobata*, Rve., = *C. ? dorsata*, var. *bilobata*, Maz. Cat., nor from the supposed *C. dorsata* in Mus. Cum.]
15. *Crepidula nummaria.* [Described from an aberrant, worn, and rounded specimen. The normal state is *C. navicelloides*, Nutt. When grown in hollow bivalves, it becomes *nummaria*: the contrary extreme, grown in crypts of borers, with another shell or crab over it, is *explanata*, Gld., = *exuviata*, Nutt., = *perforans*, Val. The Lessonoid form is *C. fimbriata*, Rve. The young appears to be *C. minuta*, Midd. But the "*C. nummaria*, Gld.," of Mus. Cum., is quite a distinct species, not known from the American coast.]
50, 244. *Natica (Lunatia) caurina* + } [= *L. pallida*, Br. & Sby.].
50, 244. *Natica (Lunatia) soluta* }
50, 244. *Natica (Lunatia) algida*; "R. Negro," E. E. Shells; "Oregon," E. E. Moll. [verè: = young of *L. Lewisii*, Gld., July 1847, = *L. herculæa*, Midd., 1849].
52. *Lacuna carinata*, Gld., Nov. 1848 [*L. solidula*, Lov., 1846. Finmark].
52, 245. *Litorina patula*, Gld. [non Jeffr.], Mar. 1849, = *L. planaxis* [Nutt.], Phil., 1847.
52, 53. *Litorina lepida*, *scutulata*, et *plena* [are shown by large series to be varieties of one species].
99. *Litorina cincta*, Gld., Aug. 1847, Puget Sd. [= *L. Sitchana*, Phil., 1845. This species appears to have been overlooked in the E. E. Moll.]
61. *Cerithium irroratum*, Gld. [= *C. obesum*, Sby sen., teste H. Cuming. The type proves this to be an E. I. species, and not the Panamic *C. stercus-muscarum*, Val., as supposed by Dr. Gld.: v. C. B. Ad. *in loco*].
62. *Cerithium filosum*, Gld., May 1849 [= *Turritella Eschrichtii*, Midd., 1849, (*Bittium*). Comp. *C. filosum*, Phil., Z. f. M. 1848, p. 84. California].
64, 245. *Fusus (Bela) fidicula.*
64, 245. *Fusus (Trophon) Orpheus* [(non Baird.) = *T. Fabricii*, Moll., in Br. Mus.]
67, 245. *Buccinum (Nassa*, s. g. *Tritia) fossatum.* *Cæsia* in Ind. p. 253. [= *N. elegans*, Rve., 1842, non Dujardin: = *Zaphon e.*, Add.].
70, 245. *Nassa (Tritia) mendica* = *N. Woodwardi*, Fbs., 1850 [from types: + *N. Gibbesii*, Coop.].
71, 245. *Columbella (Alia) gausapata.* [Belongs to the Nassoid group, *Amycla.*]
75. *Mya præcisa* [= *M. truncata.* Scarcely even a variety; but approaches the form *Aldrovandi.*]
76, 245. *Lutraria (Tresus) capax.* [Dr. G. revives his excellent name; *L. maxima*, Jonas, 1844, being anterior to Midd. Conrad's name, *Schizothærus Nuttallii*, is, however, very much earlier.]
77, 246. *Osteodesma (Lyonsia) bracteatum* [+ *O. nitidum*, Gld., in different states of preservation, = *L. Californica*, Conr. The "golden nacre" of *O. bracteatum* is due to incipient decay, as generally happens in Anomiads].
83, 246. *Cardita (Actinobolus) ventricosa.* [Appears to be a local variety of the ancient Miocene species, *Venericardia borealis*; + *C. occidentalis*, Conr., + *C. subtenta*, Conr. (fossil) probably.]
83. *Cardium blandum*, 1850. [A finely grown ?var. of *C. Californiense*, Desh., 1839, Midd. (non *C. Californianum*, Conr., 1837, = *corbis*, var.) = *C. pseudofossile*, Rve., 1844. The name is so like the preoccupied *Californianum* that it may advantageously be dropped.]
85. *Venus rigida*, 1850 [non Dillw. 1817. It is fortunate that the name is not needed, as the author has joined two very different species, both of which have other names. The original Latin diagnosis applies to the rough northern form of *Tapes staminea*, Conr., which is the *Saxidomus Petitii* of Desh., and includes *V. ruderata*, Desh. But the "specimen, $3\frac{3}{4}$ in. long," which modified the description in the E. E. Moll., and is figured at f. 538, proves to be the adult form of *Tapes tenerrima*, Cpr., P. Z. S. July 1856, which is a Californian and not a Panamic species, as had been supposed from Col. Jewett's label].
87, 246. *Anodonta cognata* = *A. Oregonensis*, Lea (probably).
87. *Anodonta feminalis* [= *A. angulata*, var., teste Lea].

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93. *Mytilus (Modiola) flabellatus.* [The northern form of *Modiola recta*, Conr. The "specimens from the Gulf of California" must have been *M. Braziliensis*, intermixed by accident.]

94. *Mytilus trossulus* [is scarcely a variety of *M. edulis*, which is very abundant along the coast, under its usual modifications of form and colour; but generally of small size].

95. *Pecten hericeus*, Gld. [=*P. hastatus*, Sby. sen.].

97, 246. *Terebratula (Waldheimia) pulvinata.*

97, 246. *Terebratula (Terebratella) caurina.*

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Page.

113. *Planorbis corpulentus* is of Say.

143. *Melania plicifera* is of Lea.

436. *Anodonta angulata* is of Lea.

206. *Scalaria ?australis* [is abundantly confirmed from the Vancouver district. It should be called *Opalia borealis*, Gld.].

244. *Purpura ostrina*, Gld., 'Otia,' p. 225 [is an aberrant smooth var. of *P. lapillus*, Coop., non Ln.; the normal state being *P. saxicola*, Val.].

The following species, described in the 'Otia' and 'E. E. Moll.' as from 'N. Zealand' and an unknown locality, are really from Puget Sound.

Otia, Page.

56, 245. *Trochus pupillus*, Gld., March 1849: N. Zealand (*Ziziphinus* in Index):= *Margarita calostoma*, A. Ad., 1851. Comp. *T. modestus*, Midd. [which is, however,=*ligatus*, Gld.,=*costatus*, Mart. This species is named in the B. M. Col. "*M. costellata*, Sby.," but is distinct, teste A. Ad. & Mus. Cum.].

64, 245. *Fusus (Neptunœa) incisus*, Gld., May 1849. Hab.?— [=*Tritonium (Fusus) Sitchense*, Midd., 1849,=*Buccinum dirum*, Rve., 1846.]

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210. *Venus calcarea* [is correctly described by Dr. G. as from N. Zealand; although quoted by him as the Oregon analogue of *V. mercenaria*].

211. *Tellina Californica*, Conr. [=*Macoma inconspicua*].

211. *Triton tigrinum* [is from Central America, not] Puget Sd.

211. *Pecten Fabricii*, Phil. [is the young of *Islandicus*: Dr. G.'s shells are the young of *P.* ("*rubidus*, ?var.") *Hindsii*].

211. *Fusus cancellinus.* [Dr. G.'s shells are *Ocinebra*, var. *aspera*.]

212. *Purpura lagena*, Gld. [MS., is probably *saxicola*, var.].

213. *Pecten Townsendi* [has not been identified].

213. *Venus ampliata* [is believed by Dr. G. to have been first designated by him as a species, afterwards proved=*rigida* (*Petitii*), var.].

44. *Middendorff.*—The synonymy given in Rep. pp. 214–222 is that of the author, not of the writer of the Report, who is by no means prepared to accept the learned doctor's identification of species. The three Chitons quoted with doubt from Tilesius have not been confirmed, as from Kamtschatka, by any other writer. The *Ch. giganteus* has the aspect of the large *Ischnochiton Magdalensis*; the *Ch. muricatus* belongs to the *Lophyrus* group, which is not known so far north; and the *Ch. setosus* has also a S. American aspect. The treatise "De *Chitone Giganteo* Camtschatico additamentum ad Zoographiam Rosso-Asiaticum, auctore Tilesio," was read March 19, 1823, and published in 1824. It contains a very valuable and (for that period) remarkable account of the anatomy of Chitons, but it does not profess to name and describe species in the modern sense. The names, therefore, had better be dropped. Middendorff's new species were first described in the 'Bulletin de la Classe Physico-Mathématique de l'Académie Impériale des Sciences de St. Pétersbourg,' a work of which few complete copies are known in England, under the following dates.

April 20, 1847: vol. vi. No. 8 (total number 128).

Column.
116. *Chiton Stelleri*, n. s.,=*C. amiculatus*, Sby., Rve., non Pallas.
117. *Chiton Pallasii*, n. s.
117. *Chiton Brandtii*, n. s.
118. *Chiton Mertensii*, n. s. [*Ischnochiton*].
118. *Chiton Eschscholtzii*, n. s.
119. *Chiton Wosnessenskii*, n. s. [A typical *Mopalia*: mantle indented behind.]
120. *Chiton Merckii*, n. s. [=*Ch. lignosus*, Gld., July 1846:=*Mopalia Montereyensis*, Cpr.].
120. *Chiton lividus*, n. s.
121. *Chiton scrobiculatus*, n. s., California.
121. *Chiton Sitchensis*, n. s.

Nov. 1847 (read April 28): vol. vi. No. 20 (total number 140).

317. *Patella* (?*Acmæa*) *ancyloides*, n. s. [Probably a delicately grown young *patina*: the diagnosis, however, suits *textilis*. Name afterwards altered to *personoides*, to distinguish from *Propilidium ancyloide*, Fbs.]
318. *Patella* (?*Acmæa*) *æruginosa*, n. s. [Probably=*textilis*, Gld., 1846; but the figure is more like *scabra*, Nutt.]
318. *Patella* (?*Acmæa*) *pileolus*, n. s. [Probably the young of *A. pelta*; but assigned in Mus. Cum. to a very different shell,=*A. rosacea*, Cpr.]
318. *Patella* (?*Acmæa*) *Asmi*, n. s. [A specimen of *A. pelta*, in Dr. Cooper's collection, began life as *A. Asmi.*]
319. *Patella* (?*Acmæa*) *cæca*; genuina, vertice erecto, Atlantic.
319. *Patella* (?*Acmæa*) *cæca*, var. *concentrica*; vertice subinflexo; with crowded lamellæ of growth.

1849; read Oct. 6, 1848: vol. vii. No. 160. "Vorläufige Anzeige einiger neuer Konchylien aus den Geschlechtern: *Litorina*, &c., von Dr. A. Th. v. Middendorff."

241 no. 1. *Litorina grandis*. [The specimens in B. M. and Mus. Cum. appear to represent a large var. of *L. litorea.*]
242 2. *Litorina Kurila* (like *tenebrosa*).
242 3. *Litorina subtenebrosa*. [Probably an extreme var. of *L. Sitchana.*]
243 4. *Tritonium* (*Fusus*) *antiquum*, Ln., var. *Behringiana*.
243 5. *Tritonium* (*Fusus*) *Behringii*.
243 6. *Tritonium* (*Fusus*) *Baerii*.
244 7. *Tritonium* (*Fusus*) *Sitchense* [probably=*Chr. dirus*, Rve., var.; but stated to be "e livido viridescente; columella sæpius umbilicata"].
244 8. *Tritonium* (*Fusus*) *luridum* [=*Vitularia aspera*, Baird, smooth form].
244 9. *Tritonium* (*Buccinum*) *simplex*.
244 10. *Tritonium* (*Buccinum*) *Ochotense*.
245 11. *Tritonium* (*Buccinum*) *undatum*, Linn., var. *Schantarica*.
245 12. *Tritonium* (*Buccinum*) *ooides*.
245 13. *Bullia ampullacea* [is the genus *Volutharpa* of Fischer].
246 15. *Natica herculæa*, North California [=*L. Lewisii*, Gld., July 1847].
246 16. *Margarita arctica*, Leach, var. *major*.

In the text of the 4to volumes, the following corrections are suggested, the numbers referring to the page in the B. A. Report which contains the abstract.

Report, 215. *Acmæa scutum*, D'Orb. [is quite distinct from *A. persona*, Esch. The latter, as figured by Midd., is a very young shell, not certainly belonging to the species].
216. *Turritella Eschrichtii*. [=*Bittium filosum*, Gld., May 1849. There being no month-date to Midd.'s species, the excellent name of Gld., which may also be of Phil. 1848, should be retained.]
216. *Trochus ater* and *mœstus* [are well-marked South American species. Probably the shells intended are *Chlorostoma funebrale*, A. Ad., and its congeners.]
216. *Trochus euryomphalus* [=*Phorcus pulligo*, Mart., teste Dohrn].
216. *Trochus modestus*, Md. [=*filosus*, Wd.,=*Calliostoma costatum*, Martyn].
216. *Trochus* (*Turbo*) *Fokkesii* [is from the peninsula of Lower Cal.].
216. *Natica flava*, Gld. ["is entirely different from any of the synonyms under it," teste Gld.].

Report, 216. *Scalaria Ochotensis* [appears an aberrant *Opalia*; but is the genus *Acirsa* of Mörch, closely allied to *Mesalia*, teste A. Ad.].

216. *Crepidula Sitchana* [is figured like the young of *grandis*; but the specimens in Mus. Cum., when compared with the similar stage of *C. excavata*, display no differences either inside, outside, or in the nuclear whorls].

216. *Crepidula minuta* [appears the young of *C. navicelloides*, Nutt.]

216. *Crepidula grandis* [fossil at Sta. Barbara, = *C. princeps*, Conr. Can hardly be distinguished from very fine specimens of *C. fornicata*, sent from Halifax, Nova Scotia, by Mr. Willes].

217. *Trichotropis cancellata*, Hds. [is quite distinct from *T. borealis*].

217. *Purpura decemcostata*, Midd. [= *P. canaliculata*, Ducl. Var. = *P. attenuata*, Rve. Var. = *P. analoga*, Fbs.]

217. *Tritonium (Trophon) clathratum*, Ln. [is distinct from the shouldered *M. multicostatus*, Esch., = *Gunneri*, Lov.].

217. *Tritonium (Fusus) decemcostatum* [= *Chr. Middendorffii*, Cooper = *Chr. liratus*, Martyn.]

218. *Tritonium (Buccinum) cancellatum* [Midd., non] Lam. [= *Priene Oregonensis*, Redf. *P. cancellata* is the Cape Horn species. Some specimens in alcohol in Sir E. Belcher's collection, however, said to be from Icy Cape, greatly resemble the southern shell].

218. *Tritonium (Pollia) scabrum* [is exclusively a S. American shell. Dr. M.'s shell may have been *Ocinebra*, var. *aspera*].

218. *Pecten rubidus*, Hds. [non Martyn, = *P. Islandicus*, Müll. Midd.'s pl. 13. f. 1–3 are marked in expl. of plates "*Islandicus*, var. *Behringiana*;" they are probably ("*rubidus*, ?var.") *Hindsii*. But the figs. 4–6 are certainly the young of *Hinnites giganteus*].

219. *Venerupis gigantea*. [Decorticated specimens of *Saxidomus squalidus*.]

219. *Petricola gibba*. [Elongated form of *cylindracea*, Desh., = *carditoides*, var.]

219. *Machæra costata*. [The figures represent *M. patula*, Dixon.]

220. *Cingula minuta* ["is quite distinct from *Hydrobia ulvæ*," teste Gld.].

220. *Velutina cryptospira*. [Probably a *Lamellaria*.]

220. *Purpura Freycinettii*, Desh. [is quite distinct from *attenuata*, Rve. It is doubtful whether Midd.'s shells belong to Desh.'s species].

221. *Terebratula frontalis*, Midd. 1851, named in 1849, [may be the young of *Waldheimia Coreanica*, Ad. & Rve., 1850, = *Terebratella miniata*, Gld., 1860, teste A. Ad., Rve.].

221. *Astarte lactea*, Gld. [is distinct from *A. Scotica*, teste Gld.].

221. *Tellina fusca*, Say [is distinct from *T. solidula*, though it may = *T. balthica*; teste Gld. *Macoma inconspicua*, Br. & Sby., is distinct from both].

222. *Lyonsia hyalina* [is distinct from *L. Norvegica*].

222. *Machæra costata*, Say. [Dr. Gould does not believe that any of Midd.'s synonyms belong to this species. *Solen medius*, in Br. Mus., appears = *S. ambiguus*, Lam., as figured by Swains. It is not a *Machæra*.]

45. *Samarang.—Litorina castanea*, Ad. & Rve., 1850. "Eastern Seas," p. 49, pl. 11. f. 8 [appears identical with *L. Sitchana*, Phil.].

46. *E. B. Philippi.—Columbella tæniata*, Phil., 1846 [is probably identical with *Anachis Gaskoinei*, Cpr. But *C. tæniata*, Ad. & Rve., 1850, is perhaps a *Nitidella*].

47. *The "Mexican War Naturalists."*—These were Major Rich and Lieut. Green. Col. E. Jewett was not connected with the war, as would be supposed from the introduction to Dr. Gould's pamphlet. The following corrections apply to the new species tabulated in Rep., pp. 226–228. The species of Gould bear date April 1852 (teste Otia, p. 184) and Nov. 1851 (Otia, p. 210); the others, July 1856.

No.

3. *Corbula polychroma* [= *C. biradiata*, var.].

7. *Tellina tersa* [= *Macoma nasuta*, jun. Cal., not Pan.].

No.
8. *Tellina pura* [=*M. Mazatlanica,* jun. Desh., Mus. Cum.].
11. *Donax flexuosus* [=*D. Lamarckii,* Desh., in B. M.].
13. *Gnathodon mendicus* [=*G. trigonum,* Pet., May 1853].
15. *Raëta undulata* [is distinct from *Harvella elegans*].
20. *Cardium luteolabrum* [=*C. quadragenarium,* Conr.].
21. *Cardium cruentatum* [=*Liocardium substriatum,* Conr.].
27. *Modiola nitens* [=*M. subpurpureus,* Mus. Cum., and is not from Cal.].
28. *Adula falcata.* [The locality of Mr. Cuming's specimens has not been confirmed. For "species," in note, read "specimens."]
31. *Lima tetrica.* [The specimens from the Mediterranean, W. Indies, Gulf Cal., and Pacific Islands were all named *L. squamosa* by Mr. Cuming.]
33. *Bulimus vesicalis* (nom. preoc.)=*B. sufflatus,* 'Otia,' p. 184.
40. *Nacella paleacea.* [Col. Jewett's specimens appear distinct from *N. depicta,* Hds.]
41. *Trochus marcidus.* [This shell was called *Omphalius Pfeifferi* by Mr. Cuming, from the resemblance of the figure, in which the umbilicus appears keeled; but the shell marked 'type,' answering to the diagnosis, along with '*Chlorostoma*' *maculosum,* A. Ad., are scarcely varieties of *Phorcus pulligo,* Martyn. The finest series is in the B. M.]
43. *Livona picoides* [has been heard of, but not seen since the explorations of Col. J. Dr. Gld. still considers the species distinct: among the very dissimilar varieties from the W. Indies (*vide* suite in B. M.) it would probably not have been singled out as a species, but for the theory of the author].
45. *Crucibulum Jewettii* [should be *corrugatum,* P. Z. S.].
47. *Modulus dorsuosus.* [Col. J. now thinks that the supposed Acapulco specimens are W. Indian, =*lenticularis,* Chem. When dead, the forms from the two oceans can hardly be distinguished; but the aspect of his shells is Caribbæan.]
54. *Conus ravus* [=*C. Californicus,* Hds.].
56. *Conus pusillus,* Gld. [non Chem. =*nux,* small var., teste Cuming].
57. *Obeliscus achates* [=*O. clavulus,* A. Ad., 1854].
65. *Columbella Sta.-Barbarensis* [so named to correct the statement that California was above the limit of the genus, proves to be a Mexican shell, and was probably obtained at Acapulco. Having been redescribed by Reeve from perfect specimens, it may stand as *C. Reevei*].
66. *Nitidella Gouldii.* [Not to be confounded with *Col. Gouldiana,* Agass., which is probably *Amycla.*]
67. *Fusus ambustus* [is a Californian species. The type stands in Mus. Cum. as *F. fragosus,* Rve., but does not answer to the diagnosis. The typical *fragosus* is marked *fragosus,* var. *F. ambustus* appears absolutely identical with *F. clavatus,* Brocchi, Mediterranean. Some of the diagnostic marks are not constant in the specimens].

Col. Jewett went to Panama, as a private collector, in January 1849, spending ten weeks in that region, including Taboga. This was two years before Prof. Adams's explorations. Thence he sailed to San Francisco, where he spent four months in exploring the shore for about 50 miles from the head of the bay. After labouring for a week at Monterey, he spent ten weeks at Sta. Barbara and the neighbourhood, thoroughly exploring the coast for fifteen miles as far as Sta. Bonadventura. It was here, at the "Rincon," after a violent southern storm, that he obtained the specimens of *Livona picoides,* as well as many other rare species that have not been obtained by any other explorer. "The storm tore up the kelp to such a degree that it formed a bank for many miles on the beach, from 10 to 20 feet broad, and at least 4 feet deep. Many of the plants were more than 60 feet long and 5 inches in diameter, having the appearance of vast cables." Before his return to the east, he also collected at Mazatlan (where he obtained some species not included in the B. M. Catalogue) and at Acapulco. There can be no doubt of the accuracy of the Colonel's observations at the time they were made. Unsurpassed in America as a field-palæontologist, possessed of accurate

discrimination, abundant carefulness, and unwearied diligence and patience, no one was better fitted to collect materials for a scientific survey of the coast. But, unfortunately for his (as for the Nuttallian) shells, he did not describe them at the time himself. They were subjected to all the derangements caused by frequent changes of residence, and transmission to various naturalists for identification. As we know what errors creep into the collections of the most learned under such circumstances, it is not surprising that they should now have lost much of their geographical value. After several days spent in a very searching elimination of the west-coast shells from his general collection, I was driven to the conclusion that several labels had become misplaced. This was so clearly the case as to certain N. England and W. Indian species interchanged with Pacific specimens, that it might also affect (*e. g.*) Sta. Barbara and Panama specimens as compared with each other. The kelp driven up by the great storm may have travelled from remote localities; which will account for tropical shells having been found at Sta. Barbara, as W. Indians occasionally are even on our own shores. It is possible also, as the Californian seas have as yet been but little dredged, that deep-water species live there which as yet are known only in the tropical province. Already some Gulf species have been thus obtained at San Diego and Catalina Island by Dr. Cooper, just as Mr. M'Andrew dredged Mediterranean species on the coast of Norway. But facts of such importance should rest on better evidence than chance shells picked on a beach, and subjected to dangers of altered labels afterwards. What was regarded by Dr. Gould as of authority is catalogued, according to his determinations of species, on pp. 226–231 of the first Report. The following is a list of the species which I found in the collection[a], divided simply into the temperate and the tropical faunas.

Species of the Temperate Fauna, collected by Col. Jewett ‡.

Pholadidea penita, ovoidea.
Saxicava pholadis.
Schizotheirus Nuttallii.
Cryptomya Californica.
Lyonsia Californica.
Solen ?sicarius, var. rosaceus *†.
Machæra patula.
Solecurtus Californianus, subteres.
Macoma nasuta, secta.
Lutricola alta.
Semele decisa, rubrolineata.
Donax Californicus, flexuosus *.
Standella ?Californica.
Trigona crassatelloides.
Psephis tantilla *.
Amiantis callosa.
Chione succincta, fluctifraga, simillima.
Tapes staminea, tenerrima *.
Saxidomus squalidus.
Petricola carditoides.
Rupellaria lamellifera.
Lazaria subquadrata *†.
Chama pellucida.
Lucina Californica.
Diplodonta orbella.
Mytilus Californianus, edulis.
Modiola modiolus, recta, fornicata *†.
Leda cælata.
Pecten hastatus, latiauritus, (?ventricosus, var.) æquisulcatus *†, squarrosus *†, paucicostatus *†.
Amusium caurinum, jun.
Hinnites giganteus.
Bulla nebulosa.

[a] This collection belongs to his daughter, Mrs. Boyce, of Utica, N.Y. The Colonel's invaluable collection of U. S. Palæozoic fossils (probably the largest made by any individual's own hand) may be consulted at the State Museum in Albany, and will probably find its ultimate destination at one of the principal colleges. A large number of the fossils described by Prof. Hall were from this collection, though often without acknowledgment. Only a small proportion of the types of the celebrated 'Palæontology' are to be found in the State Collection, which was subjected to disastrous and very extensive curtailment before Col. J. entered on his present duties as curator.

* These species and marked varieties were first found by Col. J.

† Of these forms, either not seen or not distinguished by Dr. Gould, the diagnoses are written, and will probably be found in one of the scientific periodicals for 1864.

‡ Unless otherwise stated in the list, Report, pp. 228–231, it may be presumed that these species were from the neighbourhood of Sta. Barbara.

Tornatina cerealis *, culcitella *.
Cylichna (?cylindracea, var.) attonsa *†.
Volvula cylindrica *†.
Cryptochiton Stelleri.
Mopalia muscosa.
Nacella incessa, paleacea *.
Acmæa patina, pelta, persona, scabra, spectrum, Asmi.
Scurria mitra.
Fissurella volcano.
Glyphis densiclathrata.
Haliotis Cracherodii, rufescens, splendens.
Phasianella (?compta, vars.) punctulata *†, pulloides *†, elatior *†.
Pomaulax undosus.
Trochiscus Norrisii, convexus *†.
Calliostoma canaliculatum, costatum.
Livona picoides *.
Homalopoma sanguineum.
Chlorostoma funebrale, Pfeifferi.
Crucibulum spinosum.
Crepidula adunca, dorsata, rugosa.
Hipponyx tumens *†.
Serpulorbis squamigerus.
Bittium esuriens *†, fastigiatum *†.
Cerithidea sacrata.
Litorina planaxis, scutellata.
Amphithalamus inclusus *†.
Lacuna unifasciata *.
Radius variabilis.
Luponia spadicea: Trivia Californica.
Erato columbella, vitellina.
Drillia inermis, mœsta *†.
Daphnella filosa *†.
Mangelia variegata *†, angulata *†.
Myurella simplex *†.
Conus Californicus.
Odostomia gravida *, inflata *†.
Chemnitzia tenuicula *, torquata * (et ?var. stylina *†), virgo *†, aurantia *†, crebrifilata *†, tridentata *†.
Dunkeria laminata *†.
Eulima Thersites *†.
Opalia bullata *†.
Lunatia Lewisii.
Cerithiopsis ?tuberculata, fortior *†, purpurea *†.
Marginella Jewettii *, ?polita, regularis *†, subtrigona *†.
(Volvarina varia, serrata; perhaps imported, or label changed.)
Olivella biplicata, bætica † [=petiolita, Gld., +anazora, Gld., MS. (non Ducl.) =rufifasciata, teste Cum., by error].
Purpura crispata, saxicola.
Nitidella Gouldii *.
Ocinebra Poulsoni.
Pteronotus festivus.
Columbella carinata, Hindsii.
Amycla ?Californiana, gausapata, tuberosa *†.
Nassa perpinguis, mendica.
?Anachis penicillata *†.
Siphonalia fuscotincta *†.

Species of the Tropical Fauna, collected by Col. Jewett [a].

Pholas crucigera [=lanceolata].
Dactylina laqueata.
Corbula bicarinata, biradiata, nasuta, tenuis, ovulata §, nuciformis §.
Sanguinolaria miniata *§.
Psammobia casta.
Tellina felix, puella *, punicea, "rubella."
Heterodonax bimaculatus et vars. §.
Strigilla carnaria (white and red vars.) § pisiformis §, sincera.
Semele pulchra §, venusta §.
Iphigenia altior.
Donax transversus, navicula, gracilis, carinatus, rostratus §, punctatostriatus §, *v.* cælatus §, assimilis.
Mulinia angulata.
Harvella elegans.
Trigona planulata ||, Hindsii §.
Dosinia Dunkeri.
Callista aurantia, chionæa, circinata §, tortuosa, lupinaria ||, rosea ||, *v.* puella §.
Chione amathusia, sugillata, neglecta.
Anomalocardia subimbricata, subrugosa.
Tapes grata, + vars. discors, fuscolineata.
Petricola pholadiformis, var.
Crassatella gibbosa.
Venericardia laticostata, radiata.
Lazaria affinis.
Chama frondosa, spinosa.
Cardium consors §, senticosum, procerum, obovale.
Hemicardium biangulatum §, graniferum.
Liocardium apicinum §.
Codakia tigerrina ||¶.
Lucina eburnea §, excavata §, pectinata.
Felania tellinoides §, var.
Modiola Brasiliensis, capax.
Lithophagus aristatus.
Arca grandis, tuberculosa.

[a] Unless otherwise specified, either by §, ||, or locality-marks in Rep. pp. 228–231, these species may be presumed to have come from the Panama district.
§ These species were probably from Acapulco.
|| Probably from Mazatlan.
¶ Another specimen, 3·78 in. across, is marked "Sta. Barbara" on the shell.

Scapharca bifrons *, emarginata, labiata, nux.
Noëtia reversa.
Byssoarca Pacifica, mutabilis.
Barbatia alternata, aviculoides, gradata, illota, solida.
Pectunculus inæqualis, maculatus, parcipictus §, ?pectinoides §.
Leda Elenensis, polita.
Pinna maura, tuberculosa.
Avicula sterna.
Bryophila setosa *.
Isognomon Chemnitzianum.
Pecten ventricosus, subnodosus §.
Lima angulata §.
Spondylus calcifer.
Ostrea palmula.
Anomia lampe.
Bulla Adamsi, Quoyi §.
Siphonaria gigas, lecanium § et vars. maura, palmata §.
Patella Mexicana.
Acmæa mesoleuca, mitella, vernicosa.
Fissurella rugosa, nigropunctata, ?macrotrema §.
Glyphis inæqualis, alta.
Phasianella perforata.
Callopoma saxosum.
Senectus squamigerus §.
Uvanilla inermis.
Calliostoma lima, Leanum §.
Tegula pellis-serpentis.
Omphalius Panamensis, coronulatus *, ligulatus ||, viridulus.
Nerita Bernhardi, scabricosta.
Neritina picta, Guayaquilensis, intermedia [" =globosa, *Brod.*"].
Crucibulum imbricatum, spinosum, umbrella, radiatum, pectinatum *, corrugatum *.
Galerus conicus, mamillaris.
Crepidula aculeata §, excavata, incurva.
Hipponyx barbatus, Grayanus.
Aletes centiquadrus.
Vermetus eburneus.
Bivonia contorta, albida.
Petaloconchus macrophragma.
Turritella goniostoma.
Cerithium maculosum, uncinatum, mediolæve, interruptum, alboliratum.
Rhinoclavis gemmata.
Cerithidea Montagnei, varicosa.
Litorina aspera, conspersa, Philippii.
Modulus catenulatus, ?disculus.
Rissoina firmata*, fortis*, expansa *†||, stricta §, Janus *, Woodwardii ||.
Planaxis nigritella, planicostata.
Radius avena §, similis.
Carinea emarginata, jun.
Aricia punctulata.
Trivia pustulata, pulla, Pacifica §.
Erato scabriuscula §, Maugeriæ.
Strombus galeatus, gracilior, granulatus.
Terebra robusta.
Euryta fulgurata, aciculata §.
Pleurotoma funiculata.
Drillia albovallosa, aterrima, ?exarata §, incrassata, nigerrima, rudis, hexagona, ?gracillima, var.
Mangelia subdiaphana §, hamata *†, cerea *†, ?pulchella.
Cithara stromboides § [? =triticea, Kien.].
Daphnella casta §.
Conus gladiator, mahogani, nux, purpurascens, regularis.
Solarium granulatum.
Torinia variegata.
Obeliscus achates *||.
Chemnitzia cælata *†.
Scalaria Hindsii *.
Alora Gouldii *.
Cancellaria bulbulus, clavatula, decussata, goniostoma, tessellata, mitriformis.
Natica maroccana et vars., Souleyetiana, zonaria §, catenata §.
Polinices otis, uber.
Neverita patula §.
Ficula ventricosa.
Malea ringens.
Bezoardica abbreviata.
Levenia coarctata.
Persona ridens [? =] constrictus.
Triton lignarius, tigrinus, ? pileare, jun.
Priene nodosa.
Ranella cælata, nitida, triquetra, pyramidalis [like *anceps* and *producta*, Rve.].
Fasciolaria granosa, tulipa, jun. [? imported].
Latirus castaneus, ceratus, rudis, tuberculatus.
Leucozonia cingulata.
Mitra lens, funiculata, nucleola.
Strigatella tristis.
Lyria harpa.
Marginella cærulescens, polita (?§).
Persicula imbricata §.
Volvarina triticea §, varia §, serrata §, fusca § [some of these are assigned to Sta. Barbara. West Indian specimens may have been intermixed: *vide* Cape St. Lucas list, *infrà*].
Oliva angulata, porphyria.
Olivella anazora, gracilis §, inconspicua, semistriata, tergina, volutella, zonalis, Zanoëti.
Agaronia testacea.
Harpa crenata.
Purpura biserialis, melo, patula, triangularis, triserialis.
Cuma tecta, kiosquiformis.

Rhizocheilus nux.
Vitularia salebrosa.
Ocinebra erinaceoides.
Monoceros brevidentatum.
Sistrum carbonarium §.
Nitidella cribraria.
Columbella festiva, fuscata, labiosa, major, Reevei *§, uncinata §, ? millepunctata, *var.* §
Conella coniformis.
Truncaria modesta.
Nassa collaria *, corpulenta, crebristriata, luteostoma, pagodus, scabriuscula, tegula, versicolor, complanata, Stimpsoniana *, nodicincta.
Phos gaudens.
Pyrula patula.
Engina Reeviana, crocostoma.
Anachis Californica *§, coronata, costellata, fluctuata, lyrata, nigricans, parva, pygmæa, diminuta *, rugosa, varia.
Strombina bicanalifera, gibberula, recurva.
Pisania gemmata, insignis, pagodus, ringens, sanguinolenta.
Northia pristis.
Clavella distorta.
Murex recurvirostris, [? =] nigrescens (*Cum.*).
Muricidea alveata §, dubia, vibex, "pinniger, *Brod.*"

This list, of about 133 species from the northern and 328 from the southern fauna (nearly twice as large as that sent by Dr. Gould and printed in the first Report, and yet not containing several species there quoted), is an instructive instance of what may be accomplished in about three-quarters of a year, simply by picking up shore-shells. It contains about 48 species in the northern and 22 in the southern faunas not previously described.

Besides the recent shells, Col. Jewett brought home a very interesting series of Pliocene fossils from the neighbourhood of Sta. Barbara. Almost all of them are species known to inhabit neighbouring seas, and are chiefly northern forms. Of some no recent specimens have yet been found in such perfect condition. The following is a list of the species, which is of the more value as they have not been intermixed with those of any other locality, and the spot does not seem to have been discovered by any succeeding geological explorer. It was two miles from the coast, and 150 feet high.

Schizotheirus Nuttallii.
Mactra planulata.
Chione succincta *.
Pachydesma crassatelloides.
Psephis tantilla, ?salmonea.
Rupellaria lamellifera.
Cardium graniferum *.
Venericardia *v.* ventricosa †.
Lucina Californica.
Pecten floridus *.
Hinnites giganteus.
Planorbis, sp.
Calliostoma costatum.
Margarita pupilla †.
Omphalius aureotinctus.
Galerus fastigiatus †.
Crepidula grandis † [*Midd.*, = princeps, *Conr.*, 3·5 inches long].
Crepidula adunca.
„ navicelloides.
Turritella Jewettii, n. s.
Bittium rugatum, n. s.
„ armillatum, n. s.
„ filosum †.
Lacuna solidula †.
Chrysallida, sp.*
Opalia (?crenatoides, var.) insculpta *, n. s.
Lunatia Lewisii.
Natica clausa †.
Priene Oregonensis †.
Olivella biplicata.
Columbella carinata.
Amycla gausapata.
„ tuberosa, n. s.
?Truncaria corrugata.
Nassa fossata.
„ mendica.
Purpura crispata.
Ocinebra lurida.
Trophon tenuisculptus †, ?n. s. [may prove identical with *T. fimbriatula*, A. Ad., Japan].
Trophon Orpheus †.
Fusus ambustus.
Pisania fortis *, n. s.
Chrysodomus carinatus †, Brit. Mus. [probably = *despectus*, var.].
Chrysodomus tabulatus, jun. †, n. s.
„ dirus †.

* These species are of a southern type.
† These forms rank with the northern series. The rest belong to the present Californian fauna.

The following fossils were also collected by Col. Jewett:—

Purpura crispata } San Francisco, 160 ft.
„ ostrina } above the Bay.

Tellina congesta, *Conr.* Monterey.

Scalaria: can scarcely be distinguished from *planicostata*, Kien., in Brit. Mus. (? = *Grœlandica*): Panama.

The collections of Major Rich, having been tabulated by Dr. Gould simply as from Upper or Lower California, I had expected to find of but little geographical value. They proved, however, to be of peculiar interest. Major Rich had been one of the naturalists in the U. S. Expl. Exp., and his warlike occupations did not prevent his remaining long enough at particular stations to pay close attention to the Molluscs. His forte lay in procuring shells in the best possible condition; and a study of them was very serviceable in explaining the dead shore-shells usually obtained from other sources. Fortunately, he was quite aware of the importance of geographical accuracy, and arranged those obtained at different places in separate drawers. The "Upper Californian" collections were made at Monterey, San Francisco, San Diego, and San Pedro; the "Lower Californian," in the Gulf, principally at La Paz, partly at San Jose and Mazatlan. At the latter place he met M. Reigen, who had filled his house with decomposing molluscs to such an extent as to induce the neighbours to have recourse to the police. From him he obtained many species not in the Brit. Mus. Cat., and probably sent to Europe in the Havre collection. Major Rich's beautiful series may be consulted at his residence, opposite the British Legation, Washington, D. C.; and are designed ultimately for one of the public museums in the neighbourhood. The following is a list of the species:—

Shells collected by Major Rich, from the Californian Fauna.

Pholadidea ovoidea [1 2].
Parapholas Californica [1]. (The young is very acuminate, with imbricated cups, as in *P. calva.*)
Netastoma Darwinii [1].
Saxicava pholadis [1 3].
Platyodon cancellatus [4].
Schizotheirus Nuttalli [4].
Cryptomya Californica [1].
Thracia curta [1].
Lyonsia Californica [1].
Mytilimeria Nuttalli [1]. (Very fine, with ossicle.)
Solen sicarius [3].
Machæra patula [1].
Solecurtus Californianus [3].
Sanguinolaria Nuttalli [4].
Psammobia rubroradiata [1].
Macoma nasuta [1], secta [1 4].
Scrobicularia alta [4].
Semele decisa [4].
Cumingia Californica [1].
Donax Californicus [1].
Mactra Californica [1].
Pachydesma crassatelloides [1 4].
Amiantis callosa [4].
Chione succincta [4].
Tapes staminea et vars. [1 2 4], laciniata [1 *].
Petricola carditoides [1].
Rupellaria lamellifera [1].
Chama Buddiana [4].
Cardium Nuttalli [4].
Lucina Californica [1].
Diplodonta orbella [4].
Kellia Laperousii [1].
Mytilus Californianus [1], edulis [1], *v.* glomeratus [*4].
Septifer bifurcatus [1*].
Modiola modiolus [1].
Lithophagus attenuatus [1].
Adula falcata [1*].
Pecten *v.* æquisulcatus [4], monotimeris [1].
Hinnites giganteus [1].
Placunanomia macroschisma [1].
Bulla nebulosa [4].
Katherina tunicata [1].
Mopalia muscosa [1], Hindsii [1].
Nacella incessa [2].
Acmæa persona [2], pelta [2], spectrum [2], scabra [2], et var. limatula † [2].
Lottia gigantea [2].
Scurria mitra [2].
Fissurella ornata [4 2].

[1] Monterey. Fresh specimens of seven species from the southern fauna were also obtained at Monterey, probably from commerce.
[2] San Diego. [3] San Francisco. [4] Near San Pedro.
* These species were first found by Major Rich.

Glyphis densiclathrata [2].
Lucapina crenulata [1] (one spec. Catalina Is.).
Haliotis rufescens [1 4], Cracherodii [1 4], Kamtschatkana [1 4].
Pomaulax undosus [4].
Trochiscus Norrisii [2] (and Catalina Is.).
Calliostoma canaliculatum [1], annulatum [1], costatum [1].
Omphalius fuscescens [4].
Chlorostoma funebrale [1], brunneum [1], Pfeifferi [1].
Crucibulum spinosum [2].
Crepidula rugosa [2], adunca [2], explanata [2].
Hipponyx ?antiquatus [2], ?tumens [1].
Serpulorbis squamigerus [2].
Spiroglyphus lituella [2] *.
Litorina planaxis [1].
Trivia Californica [1].
Conus Californicus [4].
Ranella Californica [4].
Olivella biplicata [1], bætica [1].
Purpura, vars. ostrina [1], emarginata [1].
Cerostoma Nuttalli [4].
Nassa mendica [1], perpingius [1], fossata [4].
Helix, three sp.

Shells collected by Major Rich, near La Paz (west shore of the Gulf of Cal.).

(Thracia) Cyathodonta plicata.
Sanguinolaria miniata.
Tellina Cumingii.
Strigilla carnaria.
Heterodonax bimaculatus.
Iphigenia altior.
Donax navicula, punctato-str., rostratus.
Standella fragilis (common).
Mulinia angulata.
Trigona argentina, radiata, planulata.
Dosinia ponderosa.
Callista concinna, chionæa.
Chione succincta, amathusia, gnidia, pulicaria, var.
Anomalocardia subimbricata.
Tapes grata, histrionica.
Lazaria Californica.
Chama spinosa, producta, corrugata.
Cardium consors, biangulatum.
Liocardium elatum.
Codakia tigerrina (two fine specimens).
Cyrena olivacea, Mexicana.
Anodonta glauca.
Mytilus multiformis.
Modiola capax.
Arca multicostata.
Barbatia Reeviana, solida.
Pectunculus giganteus.
Pinna rugosa.
Margaritophora fimbriata.
Isognomon Chemnitzianum.
Pecten ventricosus, subnodosus.
Lima tetrica *.
Janira dentata.
Ostrea amara (Maz. Cat. 215. *Is. Crestona*, entrance of Gulf), Virginica (more pearly than the Atlantic shells, teste Rich).
Anomia lampe.
Bulimus sufflatus *, excelsus *, pallidior.
Physa elata *, aurantia.
Patella Mexicana.
Acmæa atrata, mesoleuca.
Fissurella rugosa, virescens.
Glyphis alta, inæqualis.
Haliotis splendens (three fresh specimens from a resident at San Jose).
Callopoma fluctuosum.
Uvanilla olivacea.
Omphalius rugosus, coronulatus.
Nerita scabricosta, Bernhardi.
Neritina picta.
Crucibulum spinosum, imbricatum, pectinatum, umbrella.
Galerus mamillaris, conicus.
Crepidula aculeata, onyx, nivea, unguiformis, arenata.
Hipponyx Grayanus, serratus, antiquatus.
Aletes centiquadrus.
Spiroglyphus lituella (on *Cr. umbrella*).
Turritella goniostoma, tigrina.
Cerithium maculosum, stercus muscarum.
Cerithidea Montagnei.
Litorina fasciata, conspersa.
Modulus catenulatus, disculus.
Cypræa exanthema.
Aricia arabicula.
Luponia Sowerbii, albuginosa.
Trivia sanguinea, radians, Solandri, pustulata, Pacifica.
Strombus granulatus, gracilior.
Euryta fulgurata.
Pleurotoma funiculata, maculosa.
Drillia ?inermis.
Conus puncticulatus, gladiator, purpurascens, regularis, arcuatus, nux.
Solarium granulatum, *v.* quadriceps.
Cancellaria obesa, cassidiformis, solida, goniostoma, ?candida.
Natica maroccana, zonaria.
Polinices Recluziana, bifasciata, otis.
Neverita patula.
Sigaretus debilis.
Oniscia tuberculosa.
Levenia coarctata.
Bezoardica abbreviata.
Priene nodosa.
Turbinella cæstus.
Fasciolaria princeps.

Leucozonia cingulata.
Mitra lens.
Oliva porphyria, Melchersi, Cumingii, subangulata.
Olivella tergina, gracilis, volutella (several taken alive).
Agaronia testacea.
Purpura patula, biserialis, triangularis, muricata, planospira ‡.
Nitidella cribraria.
Columbella fuscata, var.
Conella cedo-nulli.
Nassa luteostoma, scabriuscula, corpulenta.
Pyrula patula.
Fusus Dupetithouarsii.
Siphonalia pallida.
Strombina (? new, deep water, San Jose).
Pisania sanguinolenta, insignis.
Murex plicatus, recurvirostris.
Phyllonotus nigritus, brassica, princeps, bicolor.
Muricidea dubia.

Lieut. Green having been obliged to pack up his collection and leave home on professional duty, I was not able to make any critical examination of it. Capt. Dupont also, of Delaware, was one of the "Mexican-war naturalists," and made a large collection of La Paz shells during his campaign; but I had no opportunity of seeing them.

Dr. Gould notes the following corrections in Lieut. Green's list, pp. 231–234:—

Semele flavicans should be *flavescens*. | *Donax abruptus* should be *obesus*.

50. *Kellett and Wood*.—The locality-marks, on further study, display still greater inaccuracies.

Nassa Woodwardii, Fbs., Sandwich Islands [is the adolescent state of a very abundant Vancouver and Californian shell, = *N. mendica*, Gld.].

Nassa Cooperi, Fbs., Sandwich Islands. [The type is immature and in poor condition; but it is a rare Californian species, since found by Dr. Cooper.]

Trochita spirata [has not been confirmed from Gulf Cal., but appears in Brit. Mus. from St. Vincent, Cape Verd Is., on the excellent authority of Macgillivray, who did not visit the West Coast. The Cumingian specimens were from K. and W.; but the "*spirata*, var.," from Magellan and Peru, are simply turrited forms of *T. radians*].

Chlorostoma aureotincta [= *C. nigerrima* (Gmel.), Mus. Cum.; but it is unlikely that Gmelin knew the species. It is not quoted by Desh. (Lam. ix. 157): but the *Trochus in fauce nigerrimus*, Chemn. f. 1526, = *T. melanostomus*, Gmel., is a *Risella*.]

Margarita purpurata et *Hillii* [are South American shells].

Purpura analoga [is the rough irregular form of *P. canaliculata* = *decemcostata*].

" *fuscata*, Fbs. [of which one brown and one whitish specimen (immature) are preserved in the Brit. Mus. as types, is the large, smooth, rather elevated var. of *saxicola*. It belongs to the Vancouver district].

Purpura, like *decem-costatus* and *Freycinetii* [is the normal state of *saxicola*. The banded smooth var. is named in Brit. Mus. "? *Buc. striatum*, Martyn, Un. Conch. no. 7," but does not agree with the figure].

Fusus Kellettii. [This *Siphonalia*, after long remaining unique in the Brit. Mus. Col., has been twice confirmed from the San Diegan district by the Smithsonian collectors. Dr. Cooper's living specimen is 6·25 in. long; and one specimen was dredged by A. Ad. in the seas of South Japan.]

51. *Reigen*.—The type collection, presented to the Brit. Mus., contains about 8900 specimens. The first duplicate series, containing about 6000 shells, was presented to the State of New York at the urgent request of Dr. Newcomb (well known for his researches in *Achatinella*, made during his professional residence in the Sandwich Islands), and is arranged in the Albany Museum. Three other typical series were prepared for the Museums of Paris, Berlin, and St. Petersburg, and offered on the same terms, viz. that they should be arranged by the author, and preserved intact for the free use

‡ Dead shells at La Paz; two fresh specimens in deep water from San Jose; ditto, Lieut. Green.

of students; but the donations were severally declined by the respective governments. They have since been offered to the Museums of Harvard University, Cambridge, Mass.; M'Gill University, Montreal, C. E.; and the Smithsonian Institution, Washington, D. C.; and accepted on the same conditions*. The writer of the Brit. Mus. Catalogue spared no pains in his endeavours to verify the previously described species of Prof. C. B. Adams; yet a subsequent comparison of types has developed very unexpected coincidences. Those who will take the trouble to compare the two diagnoses in the synonyms now given will add one to the many proofs of the uncertainty of the senses in observation, and the inaccuracy of language in description. The following corrections and additions should be made to the list in the British Association Report, pp. 243–264.

18. *Parapholas acuminata* is united to *P. calva* by Tryon, Mon. Phol.
23. The specimens obtained from Madagascar by Sir E. Belcher in the Voy. Samarang appear absolutely identical.
24. *Petricola robusta.* The West Indian form of this species is the *Choristodon typicum* of Jonas; Mus. Cum.
35. *Sphænia fragilis* is perhaps *S. luticola*, Val.
38. *Solecurtus politus* ? = *S. Carpenteri*, Dkr.
40. Should be *Semele flavescens*, Gld.
41. *Semele ?venusta* should be *S. bicolor*, C. B. Ad. Panama. C. S. Lucas.
46. Should be *Sanguinolaria miniata*, Gld., as in first Report.
48. Should be *Tellina purpurea*, Brod. & Sby., teste type in Mus. Hanl.
49. = *T. pura*, Gld., nom. prior.
54. Quite distinct from *Tellina alternata*, Say.
56. *Tellina ?eburnea* proves to be the type of a new generic form, probably belonging to *Kelliadæ*, viz. *Cycladella papyracea.* A perfect specimen, since found, is in Mr. Hanley's collection.
65. *Tellidora Burneti* is not *L. cristata*: *v. anteà*, p. 528.
66. = *Strigilla fucata*, Gld. (not *miniata*). Specimens received from different stations on the Pacific Coast vary very greatly in colour and markings.
68. The fragment of "?? *Psammobia*" is perhaps part of a *Lepas*-valve.
71 and 72. The names of these shells have been altered and re-altered in Mus. Cuming, as will be seen by comparing Brit. Mus. Maz. Cat., p. 43, with the note, p. 548, and with the present arrangement. Mr. Hanley states that no. 72, *D. culminatus*, Cpr., is his true *carinatus*; therefore 71, *D. carinatus*, Cpr., and of most collections, must stand as *D. rostratus*, C. B. Ad., teste type-valve in Mus. Amherst. The two species uniformly retain their distinctive characters.
78. Should be *Mactrella exoleta* = *Lutraria ventricosa*, Gld., from type.
81. Should be *Gnathodon mendicus*, Gld.
83. *T. Hindsii* is distinct, teste Hanl.
85. *T. argentata*, Sby., 1835, = *T. æquilatera*, Desh., 1839.
92–99. The generic name should be *Callista*.

* A few of the duplicate sets having been sent in exchange to one of the principal scientific dealers, he advertises a list of species in which he not merely alters the nomenclature, giving "*Monoceros*" *cingulatum*, "*Pollia*" *insignis* (with "*Pisania*" *gemmata*), "*Trochus*" *olivaceus* (with "*Imperator*" *unguis*), "*Cerithium*" *montagui* (for *Cerithidea Montagnei*), *Cytherea* "*dione*" (for *Dione lupinaria*), "*Astarte*" *Dunkeri*, "*Cytherea*" *Columbiensis*, &c., but inserts Californian species ("*Ziziphinus filosus*," "*Cardium Nutali*") as though from the Gulf, and adds others not known at all in the West Coast faunas, as "*Columbella lævigata*," "*Patella plumbea*," and "*Chiton reticulata*." All these, with such shells as *Oliva Cumingii*, which belong to other regions on the Mexican coast, would be accredited by the reader on the supposed authority of "Carpenter's Catalogue." In these times it appears that naturalists must be content to resemble the dealers in patent medicines, and guard the accuracy of their works! With regard to the Mazatlan collections (now scarce), none can be trusted unless they present an *unbroken seal*, with the initials of the author.

98. *Callista alternata* has a very different aspect from the ordinary *C. circinata*; but several of the Pacific shells affiliate more naturally to the West Indian form.
99. *C. affinis*, *C. tortuosa*, and *C. concinna* appear to be one species.
100. Sir E. Belcher is confident that he dredged *C. petechialis*, in deep water, off S. Blas. He has the same confidence in regard to some of the East Indian Circes. At this distance of time, a written locality-ticket would have had more authority.
105. The hinge proves that this species is distinct from the true *V. crenifera*, Sby. It has been named *V. sugillata* by Rve., Conch. Ic. sp. 43. It was also brought by Kellett and Wood, and is allied to *V. pulicaria*.
110. Among the Panama varieties of this very variable species is *Venus fuscolineata*. *T. grata* takes the place of the Californian *T. staminea*, which is sometimes erroneously given as a synonym, and is not *straminea*, as often quoted.
116. It appears that *Gouldia* (*Thetis*, C. B. Ad., *olim*, non Sby. nec H. & A. Ad.) is congeneric with "*Circe*" *minima*, not with the Astartids. Prof. Adams's fresh specimens of his *G. Pacifica* prove to have the Crassatelloid internal ligament, and represent one of the many remarkable forms of that group.
117. Fresh specimens of *G. varians*, from Cape St. Lucas, have also the internal ligament, and must rank under *Crassatella* until that genus has been naturally divided.
118. *Lazaria Californica*. A well-marked group of species from the West Coast.
121. The purple and orange specimens, here treated as the adolescent state of *Chama Mexicana*, are certainly the *Ch. echinata* of collections, and may possibly prove a distinct species. A large series sent from Socoro Is. by Mr. Xantus confirms this view; but all the specimens seen are decorticated or incrusted.
121*b*. This is the *Chama Buddiana* of C. B. Ad., and probably distinct.
134. The specimens of *Cardium graniferum* in Mus. Cum., from St. Thomas, W. I., appear exactly identical.
136. The specimens from the Pacific coast, some of which are of very large size, have generally a red tinge round the inner margin; as have also the Fiji specimens brought by the U. S. Expl. Exp. In other respects they exactly accord with the W. Indian. The Pacific shells are generally called *C. exasperata*, Rve., a name first given to the rough Caribbean variety from Honduras, &c.
137. *Codakia punctata*. This shell also, brought by the U. S. Expl. Exp. from the Fiji Is., is found sparingly along the American shores, and has the same coloured margin.
142. May possibly prove identical with *L. bella*, Conr., S. Diego.
150. The *Lucina orbella* of Gould, = *Sphærella tumida*, Conr., MS., is the northern form; uniformly larger and smoother than *Diplodonta semiaspera*. This last is fully confirmed from both oceans.
152. "*Felania*" *serricata* appears congeneric with *Miltha*, H. & A. Ad., = *Mittrea*, Gray, the type of which (*M. Childreni*) is a Gulf species.
154. *Lasea rubra*. Mr. J. G. Jeffreys does not consider the Brit. Mus. specimen identical with the British. The Mediterranean specimens are much more unlike. A colony of fresh shells from a burrow at Cape St. Lucas, when examined, under the microscope, side by side with Ilfracombe specimens, did not present even varietal differences. The species also appears on the Californian and Japan coasts. Similar and perhaps conspecific forms are found on most coasts: among them is *Poronia Petitiana*, Chen. Conch. Ill. p. 2, pl. 1. f. 2; Callao, not rare, *Petit*.
156. For this species, *corbuloides*, and other angular forms, the name *Bornia* may be revived in a restricted sense. (A. Ad.)
157, 158. Mr. A. Adams, who is about to make the Kelliads a special study, thinks that these intermediate forms would rank better with *Montacuta* or *Tellimya*.
166. This is almost certainly = *Anodonta glauca*, Val.
168. Dr. Dunker renamed this shell *M. Adamsianus*, P. Z. S. Nov. 1856.
177. The subgenus *Adula* may be enlarged to include this and other nestling ?*Lithophagi*, which often adhere by byssus, like *Modiola*.
178. *Liosolenus* is quite distinct from *Mytilimeria*, which appears simply an aberrant form of *Lyonsia*. Other "*Lithophagi*" probably rank with it.

180. *Arca senilis* is from W. Africa (not "E. Indies"): one of the many representative species between the two West Coasts.
185. *Noëtia reversa*, Gray.
186. *Argina brevifrons*, Sby.
188. This is the young of *Barbatia alternata*.
191–195 belong to the group *Barbatia*.
193. =*Barbatia Tabogensis*, from type.
203. The young of this shell is *Avicula libella*, Rve. Dr. Gould protests against some of the interpretations here given to his views.
204. The W. American pearl-oyster should stand as *M. fimbriata*, Dkr. It has been redescribed as *M. barbata*, Rve.
212. Dr. Gould protests against the Pacific shells being regarded as *O. Virginica*. Mr. Hanley adheres to his original opinion. Fossils sent from the Sandwich Is. by Mr. Pease (*O. Sandwichensis*, Pse.) appear scarcely to differ.
214*b*. The *O. palmula* appears a distinct species.
215. This species is identical with *O.* no. 384 of C. B. Ad. It may take the name of *O. amara* from its "bitter flavour."
224. *Bulla Adamsi*=*B. punctulata*, C. B. Ad., non A. Ad.
229. *Haminea cymbiformis* is closely allied to *H. virescens*, Sby.
239. *Siphonaria lecanium*. *S. maura*, Sby., is one of the varieties of this species. The *S. palmata* may prove distinct. *S. ferruginea*, Rve., is probably described from the intermediate form.
242. *Ianthina striulata*. Name given in ignorance of *striolata*, Ad. and Rve.; and not needed, teste Rve.
245. The *Dentalium hyalinum* of Phil. is probably the young of *D. semipolitum*: this species is distinct.
247. The *Dent. pretiosum* of Nutt. is a northern species; this is most likely *D. lacteum*, Phil.
248–250. This typical group of Chitonids retains the Linnean name in Dr. Gray's arrangement; and as he first pointed out the generic distinctions in the family, his judgment is to be preferred.
252–254, 256. These species belong to *Ischnochiton*, Gray.
255. *Lepidopleurus*, Risso, has sculptured valves and scaly margin, and is probably synonymous with *Lophyrus*, H. and A. Ad. The name may be retained for the "Lophyroid" *Ischnochiton* here described, the peculiarities of which have been confirmed by adult specimens in Mus. Cuming, and by other species.
257. *Chiton*, H. and A. Ad.,=*Acanthopleura* (Guild.), Gray.
262. =*Nacella peltoides*, n. s. (described from Cape St. Lucas specimens).
263. The true *Lottia pintadina* of Gld. (teste figured types) consists entirely of varieties of *A. patina*.
265. The "large flat shell" referred-to is *Tecturella grandis*, Gray, Brit. Assoc. Rep. 1861, p. 137. *Tecturella* is preoccupied by Stimps. Gr. Manan Invert. It being needful to divide the old genus *Acmæa*, *Lottia* may be used for this section. By reviving synonyms as sectional names, when a genus is divided, good names may be retained in a restricted sense, and the burden of a spurious nomenclature lessened. The species is *Lottia gigantea* (Sby. Gen.).
269. *Scutellina navicelloides*, Cpr.,=*Crepidula osculans*, C. B. Ad.
280. This should stand as *Gadinia stellata*, Sby., that name having been given to the normal form, Rep. pl. 7. f. 3*a*, of which *pentegoniostoma*, f. 3*f*, is only an accidental variety.
282. *Callopoma Fokkesii*=*tessellatum*, Rve., is the Lower Californian form, and probably distinct.
283*b*.=*Turbo phasianella*, C. B. Ad., non *Melaraphe phasianella*, Phil.
289. The first name is *T. eximius*, Rve., P. Z. S. 1842, p. 185; Mke.'s shell bearing date 1850. It appears identical with "*Javanicus*, Lam.," in Mus. Cum., and is extremely like "*speciosus*, Japan." *Trochus* being now generally retained for the *Niloticus* group, which contains the largest forms, it is best to revive Swainson's excellent name *Calliostoma* for the "*Ziziphinus*" group. A specific name should not be used for a genus, where a distinctive name has already been accurately described.

290. *Calliostoma M'Andreæ* is the normal state, of which *C. Leanum* is the pale variety.
292. Mr. Pease considers that *T. Byronianus* represents a *Polydonta* from the Pacific Islands.
313–316. The non-pearly *Liotiæ* are *Conradia*, A. Ad.
322, 323. Mr. A. Adams thinks that the "*Ethalia*" *amplectans* is probably the young of "*Teinostoma*" *a.*, as suggested in Brit. Mus. Cat. p. 253.
338. *Crepidula adunca*, Cpr. (non Sby.,=*solida*, Hds.,=*rostriformis*, Gld.). The tropical shell is *C. uncata*, Mke.,=*C. rostrata*, C. B. Ad., Rve.
341. Should stand as *C. squama*: v. note on C. B. Ad. no. 351.
354. *Vermetus eburneus*, Rve.,=*V. ?glomeratus*, C. B. Ad., non Lam. The note to *Cæcum*, Brit. Mus. Cat. p. 314, should read:—"Of a fourth group, *Meioceras*, three species are known from the Caribbean Sea, one of which is fossil at Grignon. The earliest Cæcid is the Eocene genus *Strebloceras*." *Vide* Mon. Cæcidæ in P. Z. S. 1858, pp. 413–444.
387. *Cerithium irroratum*, Gld. (teste type sp. in Mus. Smiths.), is a very distinct East Indian species,=*C. obesum*, Sby. sen.
388. This is not the *C. interruptum* of C. B. Ad., Sby., and Mus. Cum. (*hodie*), which latter is the roughened form of *C. stercus muscarum*, Val. *C. Gallapaginis* is the rough form of *C. interruptum*, Mke.
389. *Vertagus* should be changed into *Rhinoclavis*, Swains.; v. note to 289.
391–393. The genus *Triforis* should be removed to *Cerithiopsidæ*. The true "*Triforis*" *infrequens* of C. B. Ad. is a dextral shell,=*Cerithiopsis tuberculoides*, no. 557. The shell here doubtfully affiliated is probably a variety of *T. inconspicuus*.
398. *Litorina Philippii*=*L. ?parvula*, C. B. Ad., non Phil.,=*L. dubiosa*, C. B. Ad., nom. prov.
399. =*Litorina pullata*, Cpr.; described from Cape St. Lucas specimens.
409. Probably=*Rissoina firmata*, C. B. Ad.,+*R. scalariformis*, C. B. Ad.
411. "Not a *Barleeia*," teste Jeffr. MS. It seems, however, too closely allied to *B. rubra* to create a fresh genus for it, unless the animal should display differences.
412, 413. Belong to *Fenella*, A. Ad.* *F. excurvata*=?*Rissoa inconspicua*, C. B. Ad., non Alder.
417. Fresh specimens prove this to be not a dead *Hydrobia ulvæ*, but a *Barleeia*. It appears on the Californian coast, as *B. subtenuis*.
418, 421. Are very similar, and possibly conspecific forms of *Cythna*, A. Ad.
422. Is a *Gemella*, teste A. Ad.
426, 427. Belong to *Styliferina*, A. Ad.
430 *et seq.* Some of these forms may rank with *Gottoina*, A. Ad., and thus approach *Fossarus*.
437. *Luponia spurca*. This shell is quite distinct from *L. albuginosa*, to which it was supposed to belong by Dr. Newcomb. It is probably a ballast specimen.
438. Quite distinct from the Panamic *A. punctulata*.
445, 446. *Cancellariadæ* should be removed to *Proboscidifera*, teste A. Ad.
450–452. Mr. Reeve unites all these species, with several others, to *M. variegata*; which is certainly the easiest way of meeting the difficulty.
453. *Myurella rufocinerea*=*T. rudis*, Gray, teste Rve.
477. *Conus regalitatis*=*C. purpurascens*, var. Most Cones vary in the same manner.
484. *Torinia variegata*. Mr. Hanley restores to this shell the uncomfortable name of Chemn. (*perspectiviuncula*), and unites to it *areola*, Desh. A careful comparison with shells from the Pacific Islands (teste Pease's specimens) proves them to be completely identical. The "specific" names of Chemn., when simply the second word of the diagnosis, can hardly claim precedence.
486. The genera in this family have lately been revised by Mr. A. Adams. A large number of his Japanese groups are here represented. This species

* The generic names here given were assigned by Mr. A. Adams, who kindly examined the figures of the minute Mazatlan shells, all of which have been drawn under the microscope.

agrees with *Pyramidella*, sp. ind., C. B. Ad., no. 293 (not 294), and may be quoted as *Obeliscus Adamsii.*

487, 488. Belong to *Evalea*, A. Ad.

489. Is a *Syrnola*, A. Ad.

492. The peculiar appearance of the apex is due to decollation, as proved by the discovery of an adolescent and several adult specimens. It probably belongs to *Diala*, A. Ad., and = *Cingula paupercula*, C. B. Ad., no. 253.

498–500. Belong to *Miralda*, A. Ad. *Parthenia quinquecincta* = ? *Cingula turrita*, C. B. Ad., + *Rissoa notabilis*, C. B. Ad.

501, 502. Belong to *Oscilla*, A. Ad. *Parthenia exarata* = ? *Cingula terebellum*, C. B. Ad.

503–506. The "Odostomoid *Chrysallidæ*" probably rank best with *Mumiola*, A. Ad.

512. *Chrysallida ovulum* = ? *Cingula inconspicua*, C. B. Ad.; non ? *Rissoa inconspicua*, C. B. Ad. nec Alder.

513–515. Are *Pyrgulina*, teste A. Ad. The Japanese species, however, seem more like *Parthenia*, no. 497.

517. Is a *Styloptygma*, A. Ad.

520. This is not the *Chemnitzia similis* of C. B. Ad.; and is probably a variety of *Ch. Panamensis.*

523. = *Chemnitzia affinis*, C. B. Ad., pars: pars = *Ch. undata*, no. 531.

535. Is perhaps a *Mormula*, A. Ad.

545. The various shells grouped under *Aclis* require revision. Comp. *Onoba*, A. Ad., and *Ebala*, Gray, which is figured as *Aclis* in Add. Gen.

549. Ranks best with *Eulimella.*

550. This is not *Leiostraca recta*, C. B. Ad., and may be called *Mucronalia involuta.*

551. This is not *L. solitaria*, C. B. Ad., and may be called *L. producta.*

552. = *Mucronalia solitaria*, C. B. Ad.

553. Ranks best with *Eulima*, teste A. Ad.

555. *L. retexa*; distinct from *L. iota*, C. B. Ad.

556. Should be *Eulima*, teste A. Ad.

557. *Vide* note to 393.

563. Belongs to the subgenus *Seila*, A. Ad.

568. *Scalaria raricosta* is perhaps the young of *S. Elenensis.*

569. *S. funiculata* and *S. diadema*, with their congeners, should be removed from *Cirsotrema* to *Opalia.*

570. Dr. Gould dissents from the affiliation of this shell to the West African species on the ground that "he can separate the African from the Pacific shells as fast as we can hand them to him." So easily can any ordinary naturalist separate conspecific British and Mediterranean specimens, or Mazatlan and Panama specimens. It is not found in the West Temperate fauna; the "var. *Californica*" being the ordinary type from the Pacific Islands, which is much more entitled to be regarded as distinct than are the West American forms.

572. Is shown by perfect Cape St. Lucas specimens to belong to a natural group of species, resembling flattened, perforated *Phasianellæ*, to which the name *Eucosmia* may be given.

580. Appears under genus "*Lagena*, Klein,"* in Mus. Cuming; the *Argobuccina cancellatum*, *Oregonense*, &c., having received a new name, *Priene*, H. & A. Ad.

589. This belongs to *Closia*, Gray, = *Volutella*, Swains., non D'Orb.

* The names of Klein in his 'Tentamen' and 'Lucubratiuncula,' 1773, are not entitled to precedence (according to the Brit. Assoc. rules), because he evidently did not adopt the Linnean mode of binomial nomenclature. What he calls a "genus" answers more to the modern idea of chapter or section. By chance, some of his names are allowable; but, if used, the genus must be regarded as that of Adams, Gray, Mörch, or other writer who defines it. The following will serve as illustrations of Klein's "genera"—"*Sol*, *Luna*, *Stella*, &c.; *Auris*, *Anas*, *Tigris*, *Pes-anserinus*, *Tuba-phonurgica*, *Cochlea-lunaris*, *Cochlea-cœlata*, &c.; *Buccinum-lacerum*, *Buccinum-muricatum*, *Thema-musicum*, &c.; *Ostreum-imbricatum*, *Ostreum-muricatum*, &c.; *Musculus-latus*, *Musculus-mammarius*, &c.; *Tellina-arcinata*, *Tellina-virgata*, &c.; *Concha-longa-biforis*, *Concha-longa-uniforis*; *Concha-τρίλοβος*;" and, in p. 167, "*Musculus-polylepto-ginglymus*," under which remarkable *generic* name is given as the first *species* "*Arca-Noæ*." According to the now fashionable transformation of malacological nomenclature into a branch of archæological research, under pretence of justice to ancient writers, the hitherto universally understood

592. *Oliva intertincta* is very close to the young of *O. subangulata*, but differs in the chestnut stain on the columella. I have not been able to compare it with the young of *O. Cumingii.*

594. Is an abundant species in the Eastern Islands, occasionally seen in West Coast collections.

595. Belongs to *Anazola*, Gray. The remaining Mazatlan species of *Olivella* are now called *Olivina*, Gray.

598. *Olivella aureocincta*=*Oliva pellucida*, C. B. Ad., non Rve.

599. *Olivella inconspicua*, C. B. Ad., is probably the young of the colourless var. of *O. gracilis*, which must be excluded from the synonymy of *O. dama*, no. 600.

606. The figure of *Purpura biserialis*, jun., Brit. Mus. tablet 2232, is stated by Mr. A. Ad. to represent the genus *Sinusigera*, D'Orb.,=*Chelitropis*, Fbs.; just as *Macgillivrayia* is the young of *Dolium*.

611. *Rhizocheilus nux*+*R. distans*, Cpr.

612. The young of *Vitularia salebrosa* is named *Fusus lamellosus*, Hds., in Brit. Mus., and is also the "*Ranella triquetra*" of Nuttall's collection.

618. Is probably *C. baccata*, Gask., in Mus. Cum., though Mr. Gaskoin regarded it as new. The var. *obsoleta*, 618*b*, is probably *C. galaxias*, Rve.

619–622. These shells may perhaps be better studied under *Daphnella*.

631. Certainly=*N. gemmulosa*, C. B. Ad.

633. *Nassa crebristriata* may rank as a var. under *proxima*, C. B. Ad., which is probably itself a var. of *versicolor*.

639. This aberrant group of forms is now transferred to *Cantharus* in Mus. Cuming. Perhaps they rank better with *Siphonalia*, A. Ad.

653. *Anachis rufotincta* ("new," teste Gaskoin) is probably=*Col. diminuta*, C. B. Ad., in Mus. Cum., but scarcely agrees with the diagnosis, nor was the accordance noticed in the Amherst types.

659. =*P. elegans*, Gray, in Griff. Cuv. pl. 25. f. 2. (1834.)

The following species, since found, must be added to the catalogue of the Reigen Collection. The specimens are deposited in the British Museum. The descriptions of nos. 693–695 appear in the appendix to the Brit. Mus. Cat.; the remainder are ready for the press.

704. *Cellepora areolata*, Busk. On *Omphalius ligulatus*.
705. *Membranipora ?Flemingii*, Busk. " "
707. *Dactylina*=C. B. Ad., Pan. no. 516. Obtained from M. Reigen, at Mazatlan, by Major Rich.
693. *Lyonsia*, sp. ind., 1 sp.
694. ?*Montacuta chalcedonica*, 1 sp.
706. ?*Montacuta obtusa*, n. s., 2 sp. Congeneric with 157, 158.
695. *Crenella*, sp. ind., 1 sp.
696. *Pectunculus*, sp. ind., 1 sp.
697. *Cylichna Carpenteri*, Hanl., P. Z. S. 1858, p. 543, 1 sp. ?=*C. luticola*, jun.
698. *Scissurella rimuloides*, n. s., 1 sp.
699. *Vitrinella ornata*, n. s., 1 sp.
700. *Vitrinella tenuisculpta*, n. s., 1 sp.
701. ?*Vitrinella*, sp. ind., fragment.
702. *Mangelia sulcata*, n. s., 1 sp.
703. ??*Torinia*, sp. ind., 2 sp.
708. *Malea ringens*. Obtained from M. Reigen, at Mazatlan, by Major Rich.

53. *Jay's Catalogue*.—Mr. Hanley states that after the return of Prof. Nuttall, his duplicates were bought by the elder Sowerby, who sold part to

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designations of Lamarck, &c., must give way to such names as the above; and if some other 'Attempt' or 'Little Lucubration' of a year's earlier date should be disinterred from now-fortunate concealment, the most modern 'Guides' and 'Books of Genera' will have to be re-written. Klein's idea of *Argobuccinum* appears to have been that of a "Spotted Whelk," probably *Ranella argus*. *Argobuccinum*, H. and A. Ad., may stand as defined in their 'Genera' for the thin ventricose Tritons. They have, however, divided the species between *Priene* and *Lagena*.

Dr. Jay, and part to Mr. Stainforth. The specimens in Mus. Cum. were received from Dr. Jay; those in Mus. Hanley from Mr. Stainforth. In the third edition of Dr. Jay's Catalogue, 1839, appear the following species which have not been identified, and localities not confirmed.

14. *Tellina rosea*, Lam. California. [Perhaps *Sanguinolaria miniata.*]
33. *Pecten tumidus*, Brod. Upper California.
37. *Chiton incarnatus*, Nutt. "
" *Chiton textilis*, Conr. "
38. *Patella plicata*, Nutt. "
40. *Fissurella pica*, Nutt. "
41. *Crepidula squamosa*, Brod. "
" *Bulla Californica*, Nutt. "
68. *Natica varioalaris.* California.
70. *Trochus Californicus*, Nutt. Upper California.
72. *Monodonta fusca*, Nutt. "
73. *Marmorostoma planospira*, Nutt. "
" *Litorina iostoma*, Nutt. "
" *Litorina maculata*, Nutt. "
79. *Melongena occidentalis*, Nutt. "
80. *Murex sexcostatus*, Brug. "
86. *Monoceros plumbeum*, Kien. "
87. *Buccinum Boysii*, Nutt. "

54. *C. B. Adams.*—After arranging the duplicate Reigen Collection in the State Museum at Albany, New York, I proceeded to Amherst, Mass., to study the type-collection from which Prof. Adams's book was written. The result is embodied in a "Review of Prof. C. B. Adams's 'Catalogue of the Shells of Panama,' from the Type Specimens," written for the Zool. Soc. in Jan., and published in the Proceedings for July 1863, pp. 339–369. In this paper the synonymy between the Mazatlan and Panama Catalogues is pointed out, and the species assigned to the modern genera. The following are the principal corrections needed in the list, Rep. pp. 267–280. The resultsi n the succeeding paragraphs, pp. 280, 281, should be altered accordingly. (M.=Brit. Mus. Maz. Cat.)

3. *Ovula neglecta*=*avena*, var.
8. *Cypræa punctulata*; quite distinct from *C. arabicula.*
11. *Cypræa rubescens*, C. B. Ad.,=*T. sanguinea*, dead.
15. *Marginella sapotilla*, C. B. Ad., is perhaps a large form of *sapotilla*, Hds. It is destitute of the sharp posterior labral angle seen in the West Indian specimens of *cærulescens.*
33. *Oliva araneosa*, C. B. Ad.,=*O. Melchersi*, M. 591.
35. *Oliva pellucida*, C. B. Ad.,=*O. aureocincta*, M. 598, dead.
40. *Oliva venulata*, C. B. Ad.,=*O. angulata*, jun.
43. *Nassa canescens*=dead sp. of *N. pagodus.*
50. *Nassa pagodus*, C. B. Ad.,=*decussata*, Kien. [? non. Lam.]=*acuta*, M. 625.
51. *Nassa Panamensis* has the operculum of *Phos* and *Northia*,=*exilis*, Pws.
52. *Nassa proxima*+54 *N. striata*, C. B. Ad. [non Mus. Cum.=*N. paupera*, Gld.], +*N. crebristriata*, M. 633, are probably vars. of *N. versicolor.*
53. *Nassa scabriuscula*, C. B. Ad.,+56 *N. Wilsoni*=*N. complanata*, Pws.
70. *Purpura foveolata*, probably=worn sp. of *Cuma costata*, M. 610.
74. *Purpura osculans*+*Rh. Californicus*+*Rh. distans*, are probably vars. of *Rhizocheilus nux.*
81. *Columbella costellata*, C. B. Ad.,=*Anachis scalarina*, Sby.
98. *Columbella parva*, C. B. Ad.,=dead sp. of *Anachis pygmæa.*
103. *Columbella tessellata*, C. B. Ad. (non Gask.),=*A. Guatemalensis*, Rve.
110. *Cassis abbreviata* can scarcely be distinguished, in some of its many varieties, from the Texan *Bezoardica inflata.*
154. *Cancellaria affinis* scarcely differs from *C. urceolata*, M. 445.

160. *Cancellaria pygmæa*=*C. goniostoma*, jun., no. 157, =M. 446.
164. *Pleurotoma atrior*=*Drillia* v. *Melchersi*, M. 461.
169. *Pleurotoma discors*, C. B. Ad., is probably a finely developed var. of *D. aterrima*.
182. *Pleurotoma rustica*, C. B. Ad.,=worn specimens of *D. Melchersi*, no. 164.
191. *Mangelia neglecta*, probably=*M. acuticostata*, M. 473.
194, 195, 201 belong to *Cerithiopsis*.
196. *Cerithium famelicum* must stand for the West Coast Uncinoids, M. 383; the Cumingian shell, and two out of ten in the type-series, belong to *C. mediolæve*, M. 382.
198, 199, 200 are various forms of *C. stercus muscarum*, Val.; quite distinct from *C. interruptum*, Mke., and *C. irroratum*, Gld.
203. Does not correspond with the diagnosis, and must stand as *Chrysallida paupercula*, a very distinct species.
208. Is scarcely a variety of *Triforis alternatus*, no. 207.
209. Both the specimens are dextral,=*Cerithiopsis tuberculoides*, M. 557.
210. *Turritella Banksii*, C. B. Ad. (non *Rve.*)=*T. goniostoma*, jun., M. 379.
217. A dead, stunted specimen of *Cæcum undatum*, M. 371.
220. *Chemnitzia acuminata* is a very broad but typical species; not *Chrysallida*.
221. *Chemnitzia affinis*, Mus. Cum. and M. 523, has sufficient correspondence with the diagnosis; but the type=*Ch. undata*, M. 531.
222. *Chemnitzia clathratula*. The type-series contains *Chrysallida clathratula*, M. 513 and Mus. Cum.,+*Chr. communis*+*Chr. effusa*, M. 510,+*Dunkeria subangulata*, M. 537.
223. *Chemnitzia communis*, the type of *Chrysallida*, M. 507, Cpr. (vix A. Ad.). The type-series also contains *Chr. effusa*+*Chr. telescopium*, M. 508,+*Dunkeria subangulata*,+?do. var.
225. *Chemnitzia major* ranks with *Dunkeria*.
227. *Chemnitzia Panamensis* contains also *Ch. Adamsii*, M. 519,+*Ch.* ?*gracillima*, M. 530.
228. *Chemnitzia similis*, like *aculeus*; differs from *Ch.* ?*similis*, M. 520, which perhaps=*Panamensis*, var.
230. *Chemnitzia turrita*=251, "*Rissoa*, sp. ind."
231, 235, 237, 238. These species of "?*Litorina*" belong to *Fossarus*.
233. *Litorina atrata*+(adult) 257, ?*Adeorbis abjecta*, are the same (variable) species of *Fossarina*, A. Ad.
239. *Litorina parvula*, C. B. Ad. (non Phil.),=*L. Philippii*, M. 398.
244. *Rissoa firmata*+(jun.) 250, *R. scaliformis*=*Rissoina*, sp. M. 409.
246. ?*Rissoa inconspicua*, C. B. Ad. (non Ald.), does not accord with the diagnosis, but is identical with *Alvania tumida*, M. 414.
249. *Rissoa notabilis*+*Cingula* ?*turrita* belongs (with 252 and 254) to another suborder,=*Parthenia quinquecincta*, M. 498.
252. ?*Cingula inconspicua*=*Chrysallida ovulum*, M. 512.
253. *Cingula paupercula*=?*Odostomia mamillata*, M. 492,=*Diala*.
254. *Cingula terebellum*=*Parthenia exarata*, M. 501.
261. *Vitrinella minuta*. The original type accords better with *Ethalia*.
266. *Vitrinella regularis* is also an *Ethalia*.
269. *Vitrinella valvatoides*. Probably an *Ethalia*.
270, 271. Are apparently vars. of *Solarium granulatum*.
272. May be distinguished as *Torinia rotundata*, from its great superficial resemblance to *Helix rotundata*.
275. *Trochus Leanus* is a pale var. of *Calliostoma M'Andreæ*.
276. *Trochus lima* can scarcely be distinguished from *C. Antonii*, Mus. Cum., dredged in the Japan seas by Mr. A. Adams.
277. *Trochus lividus*, C. B. Ad.,=*Modulus disculus*, M. 403.
280. *Trochus reticulatus*=*Omphalius viridulus*, M. 292.
281. *Turbo Buschii*, C. B. Ad.,=*Uvanilla inermis*, M. 287,=*T. variegatus*, Gray, MS. in Brit. Mus. The true *U. Buschii* is coloured outside like *U. olivacea*, but with a white base like *U. inermis*. St. Elena, Hds. in Brit. Mus.
282. *Turbo phasianella*, C. B. Ad., is probably the perfect form of *Phasianella*, ?var.

striulata, M. 283*b*. Its operculum proves it to be a true *Phasianella*, and not *Melaraphe phasianella*, Phil., of Add. Gen.

283. *Turbo rutilus*, the worn remains of what perhaps was once *Pomaulax undosus*, brought in ballast from Lower California.
289. *Scalaria*, sp. *c*, = *Opalia funiculata*, jun., M. 569.
290. *Eulima* [*Leiostraca*] *iota* appears distinct from *L. retexta*, M. 555.
292. *Eulima* [*Mucronalia*] *solitaria* = *Leiostraca*, sp. *a*, M. 552.
293. *Pyramidella*, sp., = *Obeliscus Adamsii*, M. 486.
296. *Natica lurida*, C. B. Ad., = pale var. of *N. maroccana*.
297. *Natica otis*, C. B. Ad. (non Br. and Sby.), = *Polinices* "*Salangonensis*," C. B. Ad., no. 298.
299. *Natica Souleyetiana*, C. B. Ad., closely resembles *N. maroccana*, with larger umbilicus.
300. *Natica virginea*, C. B. Ad., + 302, *N.*, sp. ind. *b*, = *Polinices uber*, M. 576.
301. *Natica*, sp. *a*, = *maroccana*, var. *unifasciata*.
318. ?? *Truncatella dubiosa* is probably a *Paludinella*.
321. *Bulla punctulata* = *B. Adamsii*, M. 224.
322. *Bulla*, sp. = *Tornatina carinata*, M. 223.
323. *Vermetus* ?*glomeratus*, C. B. Ad., = *V. eburneus*, Rve., M. 354.
324. *Vermetus Panamensis*, C. B. Ad., = *Aletes centiquadrus*, M. 352.
325. *Stomatella inflata* is a *Lamellaria*.
326. *Hipponyx* ?*subrufa*, C. B. Ad., = *H. Grayanus*, jun., M. 350, + ?*barbatus*, jun.
327. *Hipponyx* ?*barbata*, C. B. Ad. The type-series contains *H. barbatus*, M. 349, + *H. Grayanus* + *Discina Cumingii*, M. 14 (valve).
330. *Calyptræa aberrans* is a valve of *Anomia*.
331. *Calyptræa aspersa* = *Galerus conicus*, broken, worn, and young; one sp. may be *mamillaris*.
333. *Calyptræa conica*. Most of the specimens are *G. mamillaris*, = 340, *G. regularis*; but a few may be the true *G. conicus*, worn, M. 332.
338. *Calyptræa planulata* is a young flat *C. cepacea*.
342. *Calyptræa* ??*unguis*, C. B. Ad., = *Crucibulum spinosum*, jun.
343. *Crepidula cerithicola* = *C. onyx*, jun., M. 340, + *C. incurva*, jun., M. 339.
349. *Crepidula squama*. Some of the young shells belong to *C. onyx*; one perhaps to *C. incurva*.
350. *Crepidula unguiformis*. Some of the specimens belong to this species; others to *C. nivea*.
351. *Crepidula nivea*. The type-specimens are small, poor, and rough, of the var. *striolata*, passing into *Lessonii*. Perhaps, therefore, the first name *squama* should be retained for the species (nos. 348, 349, 350, part, and 351), leaving *striolata* and *Lessonii* for the vars.
352. *Crepidula osculans* belongs to another order, = *Scutellina navicelloides*, M. 269.
353. *Crepidula rostrata*, C. B. Ad., Rve., = *C. uncata*, Mke., M. 338; and is perhaps distinct from *C. adunca*, Sby., = *solida*, Hds., = *rostriformis*, Gld.
357. *Fissurella microtrema*. Dead shells, of which part = *F. rugosa*, var. M. 273.
358. *Fissurella mus*. Intermediate between *Glyphis inæqualis*, M. 279, and var. *pica*.
361. *Fissurella virescens*. Intermediate between *F. v.*, M. 271, and *F. nigropunctata*, no. 359.
366. *Siphonaria* ?*pica*, C. B. Ad. Young dead limpets [?*Acmæa*].
367. *Lottia* ?*patina*, C. B. Ad. [non Esch.], may stand, until more specimens have been collated, as *Acmæa* (?*floccata*, var.) *filosa*.
368. *Lottia*, sp. ind. *a*, may be quoted as *Acmæa* (?*floccata*, var.) *subrotundata*.
369. *Lottia*, sp. ind. *b*, may rank, for the present, as *Acmæa* (?*vespertina*, var.) *vernicosa*.
371. ?*Patella*, sp. ind., resembles *P. vulgata*, but may be an *Acmæa*.
372–376. There was no opportunity of dissecting the Amherst Chitons; but among the remaining duplicates of the collection (all of which were obtained and brought to England) were the following:—
373. *Chiton dispar*, C. B. Ad. (? non Sby.), including *Lepidopleurus Adamsii* and var. and *L. tenuisculptus*.

375. *Chiton pulchellus*, along with *Ischnochiton Elenensis*, and ?var. *expressus*.
376. *Chiton Stokesii*. Sent as *C. patulus* by Mr. Cuming.
377–379. Probably vars. of *Anomia tenuis* (non *lampe*).
380, 381. *Ostrea*, sp. ind. *a* and *b*, a peculiar corrugated species, which may stand as *O. Panamensis*.
382. *Ostrea*, sp. ind. *c*, resembles *O. rufa*, Gld., MS. (not Lam. in Deless.), not *Columbiensis*.
383. *Ostrea*, sp. ind. *d*, more like the Gulf Mex. shells than *O. Virginica*, M. 212.
384. *Ostrea*, sp. ind. *e*, may stand as *O. amara*. The "small var." is *O. conchaphila*, M. 214.
386. *Spondylus*, sp.,=*Plicatula penicillata*, M. 210.
393, 394. *Perna*, sp. *a*, *b*,=*I. Chemnitzianum*. The Jamaica conspecific shells are labelled "*bicolor*, Ad."
396. *Pinna tuberculosa*, C. B. Ad., probably=*P. maura*, jun.
398. *Lithodomus*, sp., includes *L. aristatus*, M. 176, *L. attenuatus*, M. 173, and *L. ?plumula*, jun., M. 175.
399. *Modiola semifusca*, C. B. Ad.,=*M. Braziliensis*, M. 171. More like the Atlantic shells than are those from Gulf Cal. A specimen, undoubtedly from N. Zealand, is pronounced conspecific by Mr. Cuming.
400–401. *Modiola*, sp. ind., contains *M. capax*, M. 170, *Myt. multiformis* [=*Adamsianus*, Dkr.], M. 168, several vars., and *Adula cinnamomea*, var. M. 177.
405. *Chama Buddiana* (in poor condition)=*Ch.* (?*frondosa*, var.) *fornicata*, M. 121 *b*.
406. *Chama ?corrugata*, small valve; large one ?=*Ch. Mexicana*, reversed.
407. *Chama echinata*, C. B. Ad., ?=*Mexicana*, jun.,+*Buddiana*, jun.
414. *Arca ?aviculoides*, C. B. Ad., appears a young *Scapharca*.
419. *Arca pholadiformis*=*Barbatia gradata*, var.
422. *Arca similis*, scarcely a variety of *A. tuberculosa*, no. 425.
432. *Cardium planicostatum*, C. B. Ad., may be a worn valve of *Hemicardia biangulata*, but more resembles a ballast specimen of the W. Indian *H. media*.
435. *Venus ?amathusia*, C. B. Ad.,=*Anomalocardia subimbricata*, M. 113.
436. *Venus discors*=*Tapes grata*, M. 110, var.,+*T. histrionica*, M. 109.
442. *Venus*, sp. *b*,=*Chione sugillata*, Rve. (=?*crenifera*, M. 105).
450. *Gouldia Pacifica*, M. 116, does not belong to the Professor's genus, but is a form of *Crassatella*.
451. *Cyrena maritima*. "The discovery of *Cyrenæ* in brackish water is a fact of some importance to geologists, which was duly appreciated by D'Orb." (T. Prime, in Ann. Lyc. N. Y. 1861, p. 314.)
457. *Donax rostratus*, C. B. Ad. (non Gld., MS., and from it Cpr. in M. Appendix, p. 549), teste type-valve=*D. carinatus*, Mus. Cum. *olim*, and from it M. 71; non *D. carinatus*, Mus. Cum. *hodie*, and type, teste Hanl.,=*D. culminatus*, M. 72.
459. *Tellina cognata*=*Psammobia casta*, Rve., teste Cuming.
465. *Tellina felix*. The affiliation of this shell to *Strigilla fucata*, Gld., MS., was doubtless due to an accidental error in labelling. No. 476 is the same species, dead.
468. *Tellina puella*. Resembles *T. felix*, not ??*puella*, M. 59.
471. *Tellina simulans*. The type-valve exactly accords with the Professor's W. Indian specimens.
473. *Tellina vicina*, C. B. Ad.,=*versicolor*, C. B. Ad., MS. on label. Larger than most W. Indian specimens, which exactly accord with the Acapulcans, and are varieties of *Heterodonax bimaculatus*. The Panamic shells resemble the Lower Californian, which are *Psammobia Pacifica*, Conr.
477. *Petricola cognata*. Perfect specimens are *P. pholadiformis*, teste Cum.
478. *Saxicava tenuis*, Sby., C. B. Ad., H. and A. Ad.,=*Petricola tenuis*, H. and A. Ad. Gen. pp. 349–441, and better accords with the latter genus.
479, 482. *Cumingia coarctata*=*lamellosa*, var. M. 42.
480, 481. *Cumingia trigonularis*, M. 43.
483. *Cumingia*, sp. *c*,=M. 45, and, if not described, may stand as *C. Adamsii*.
484. *Cumingia*, sp. *d*,=M. tablet 107, p. 31.

485. *Amphidesma bicolor* = *Semele ?venusta*, M. 41 (non A. Ad.).
487. *Amphidesma proximum*, probably = 486, *ellipticum*, var.: not *Semele proxima*, M. 40, = *S. flavescens*, Gld., M. p. 548.
489. *Amphidesma striosum*, resembles *Semele pulchra*, no. 488.
491. *Amphidesma ventricosum*. Scarcely perfect enough to distinguish the genus. The valve outside resembles *Macoma solidula*.
497. *Anatina alta*. A valve of *Periploma*; probably one of the Gulf species.
498. *Pandora cornuta*, named and described from a fractured growth; resembles *Clidiophora claviculata*.
499, 500 are varieties of the same species of *Azara*, of which perhaps no. 501 is an extreme form.
506. *Corbula rubra* = *C. biradiata*, jun., no. 503, M. 31. No. 509 are dead valves of the same, = *C. polychroma*, Cpr.
508. *Corbula*, sp. *a*, resembles *C. pustulosa*, M. 32.
510. *Solecurtus affinis*, probably = *S. Caribbæus* = *Siliquaria gibba*, Spengl., S. I. Check-List, no. 222. The W. African specimens are affiliated to the same species by Mr. Cuming. The Mazatlan shells, M. 37, have a different aspect, but closely resemble the Ariquibo specimens in Mus. Amherst.
511. *Solen rudis* is named *Solena obliqua*, Spengl., in Mus. Cum. It appears identical with *Ensatella ambigua*, Lam., as figured by Deless.; but *S. ambigua* (Lam.), Swains., is slightly different, and better agrees with the dead valves of "*S. medius*, Alatska," in Brit. Mus. These may, however, be only ballast-valves. As *S. ambigua*, Lam., was described from America, and the form is not known elsewhere, it probably represents the Panamic shell.
515. *Pholas*, sp. *a*, = *laqueata*, teste Cum.
516. *Pholas*, sp. *b*, closely resembles *Dactylina dactylus*; also La Paz, teste Rich.

The following species were collected by Prof. Adams, but do not appear in his Catalogue; they were found either mixed with others in the Amherst Museum or in the shell-washings of his duplicates*.

518. Mumiola ovata.
519. Chrysallida effusa.
520. Chrysallida telescopium.
521. Chrysallida fasciata.
522. Chrysallida, n. s.
523. Leiostraca retexta.
524. Eulima yod.
525. Volutella margaritula.
526. Cæcum semilæve.
527. Cæcum subquadratum.
528. Cæcum clathratum.
529. Lepidopleurus tenuisculptus.
530. Ischnochiton Elenensis.
531. Cerithiopsis, n. s.
532. Lucina capax.
533. Kellia suborbicularis.
534. Sphænia fragilis.
535. Tellina laminata.
536. Crenella inflata.

55. *British Museum Catalogues*.—To the list of Deshayes, Cat. *Veneridæ*, may be added—

Page.
7. *Dosinia ponderosa*, Gray, = *Cyth. gigantea*, Sby., = *Venus cycloides*, D'Orb. [Gulf] California.
135. *Chione callosa* [Desh. et auct. Brit., = *Ch. fluctifraga*, var., quite distinct from *Callista (Amiantis) callosa*], Conr.
147. *Chione astartoides*, Beck, Greenland. [1849. = *Tapes fluctuosa*, Gld., 1841; teste Gld., Otia, p. 181. Midd.'s figures more resemble *V. Kennerleyi*, jun.]

The authorities are rarely given for localities quoted in this elaborate work. The same species often occur under different names. The *Veneridæ*

* With regard to the species which have received different designations in the Reigen and Adamsian catalogues, whether those names be retained of which the specimens exist, and have been widely distributed, in accordance with the diagnoses, or whether the prior ones be adopted of which the unique types do not represent the descriptions, is a matter of little moment to the writer of the Brit. Mus. Cat. He spared no pains in making-out his predecessor's species before describing his own, and has offered the best attainable list of the parallel forms in the review here quoted.

in the Brit. Mus. Coll. have received Deshayes' autograph names, in accordance with this Catalogue, generally on the back of the tablets.

In the Brit. Mus. Catalogue of *Volutidæ* *, 1855, Dr. Gray arranges the W. Coast species thus :—

Page. No.
17 7. *Lyria (Enæta) Harpa*, Adams, 167; Gray, P. Z. S. 1855, p. 61; *Hab.* Peru, = *Voluta Harpa*, Barnes, Sby., Conch. Thes. [= *Voluta Barnesii*, Gray, Zool. Journ. vol. i. p. 511, note.]
18 10. *Lyria (Enæta) Cumingii*, Brod. (*loc. cit.*). Central America, S. Salvador, Gulf Fonseca.

56. *Sailor's Coll.*—*Pecten ?senatorius* may be a form of *sericeus*, Hds.

57. *Gould's Collections.*—"*Planorbis ammon*, = *Traskei*, Lea. *P. gracilentus* ? = *Liebmanni*, Dkr., or *Haldemanni*," teste Gld. MS. The collections of Mr. Blake and others will be found under the "Pacific Railway Explorations," *v. posteà*, par. 98.

58. *Bridges.*—Some of the species described as new on Mr. Cuming's authority appear, on further comparison, to be identical with those before known.

?*Scrobicularia producta* = *Lutricola* † *Dombeyi*, Lam.

Strigilla disjuncta appears to the author identical with *S. sincera*, Hanl. ["Quite distinct," H. Cuming.]

Lyonsia diaphana = *L. inflata*, Conr.

Calliostoma M'Andreæ = normal state of *C. Leanum*, C. B. Ad.

Natica excavata + *N. Haneti*, Recl., appear varieties of *N. Elenæ*, Recl., the analogue of *lineata*, Chemn.

Add *Alora* ("*Trichotropis*") *Gouldii*, H. and A. Ad., P. Z. S. 1856, p. 369; 1861, p. 272.

59. *Proc. Zool. Soc.*—The following additional synonyms have been observed in the list, Rep. pp. 285–288 :—

Page.
1835 43. *Venus leucodon* + *Californiensis* [= *Chione succincta*, Val. 1833].
,, 110. *Pecten circularis* [? = *ventricosus*, jun.].
1850 24. Pl. 8. f. 4. (Add) *Cumingia similis*, A. Ad. N.W. coast of America.
,, 37. *Gena varia*, A. Ad. Mindoro, 9 fms., *Cuming*; Australia; Acapulco, on the sands, *Moffat*. [Clearly imported.]
1851 153. *Infundibulum Californicum* [is a Pacific shell = *I. chloromphalus*, var.].
,, 168. *Ziziphinus Californicus* [= *Calliostoma eximium*, Rve.].
,, 190. *Margarita calostoma* [= *M. pupilla*, Gld., = *costellata*, Brit. Mus. Col., non Sby.].
1853 185. *Pseudoliva Kellettii*, A. Ad. [= *Macron* (*Zemira*) *Kellettii*, Mus. Cum.: = *Pusio trochlea*, Gray, MS. in Brit. Mus. Cerros Is., *Ayres*].
1854 316. *Chlorostoma funebrale* [= *Tr. marginatus*, Nutt. (non Rve.); = *T. mæstus*, auct. nonnul.; non Jonas].
,, 359. *Tellina Mazatlanica* [= *T. pura*, Gld., 1851].
1855 231. *Chiton Montereyensis* [= *Mopalia lignosa*, Gld., 1846: = *Merckii*, Midd., 1847].
,, 231, 232. *Ch. Hartwegii* and *regularis* belong to *Ischnochiton*.

* In Donovan's 'Naturalist's Repository,' vol. ii. 1834, p. 61, appears (without authority) "*Voluta Dufresnii*, Don., California, S. America."

† This belongs to a group of species in which the cartilage is semi-internal, intermediate between *Scrobicularia* (= *Lutricola*) and *Macoma*. They are arranged under the former group in Add. Gen. ii. 409, as "subgen. *Capsa*, Bosc." That Lamarckian name being in common use for *Iphigenia*, Schum., and being also employed for *Asaphis* and *Gastrana*, it adds to the confusion to use it for a fourth group. The bulk of Blainville's old genus having migrated to *Lutraria* and *Scrobicularia*, his name may be revived for this group not otherwise provided-for. The species was redescribed in consequence of *Dombeyi* having been left among the true *Tellens* in Mus. Cum.

Page.
1855 234. *Callopoma depressum* [= *Senectus funiculatus,* Kien.: not American].

The following species appear in later numbers of the Proceedings :—

1856 360. *Mytilus Adamsianus*, Dkr. [=*M. multiformis*]. Panama, *Cuming.*
„ 365. *Volsella splendida,* Dkr. California.

Dr. Gray, in his elaborate article on the *Olividæ*, 1858, pp. 38 et seq., gives *O. julieta*, Ducl., *O. araneosa*, Lam., and *O. venulata*, Lam., as synonyms of *Strephona reticularis*, Lam.; and quotes as "species (?) more or less allied to it," *O. polpasta*, Ducl., *O. splendidula*, Ducl., "*O. jaspidea*, Dúcl., = *O. Duclosii*, Rve." [?], *O. kaleontina*, Ducl. (Gallapagos), *O. Cumingii*, Rve., and *Oliva Schumacheriana*, Beck, "California: front of pillar-lip brown" [?=*O. Cumingii*, var.].

For *O. volutella*, Lam. (including *O. razamola*, Ducl.), he constitutes the genus *Ramola.*

For *O. undatella*, Lam. (including *O. ?hieroglyphica*, Rve., *O. nodulina*, Ducl., and *O. ozodina*, Ducl.), and similar species, he forms the genus *Anazola.*

The restricted genus *Olivella* is altered to *Olivina*, and includes (from the West Coast) *O. gracilis*, Sby., *O. anazora*, Ducl., *O. tergina*, Ducl., *O. lineolata* =*dama*, Goodall*; and, in a section, *O. columellaris*, Sby., *O. semisulcata*, Gray, and *O. zonalis*, Lam.

The Californian species, *O. biplicata*, Sby., = *O. nux*, Goodall, in Wood, is placed in the genus *Scaphula*. This is constituted for an animal, "*Olivancilla auricularia*," D'Orb., on which, in his work on S. America, he figures the shell of *O. biplicata* (teste Gray). The shell might in some way have become mixed with S. American specimens; but as D'Orb. could not possibly have there observed the living animal, the genus should be restricted to the latter. The shell of *O. biplicata* is very peculiar, and has not been found south of San Diego. D'Orbigny's genus is *Olivancillaria.*

Page.
1859 280. *Terebra strigata*, Sby., Tank. Cat. Panama, Real Lejos. =*Buccinum elongatum*, Gray, Wood, = *Terebra zebra*, Kien., = *Terebra flammea*, Less.
„ 287. *Terebra Salleana,* Desh. Mexico [?ubi], *Sallé.*
„ 302. *Terebra Petiveriana*, Desh. (Pet. Gaz. pl. 75. f. 5). Panama. Mus. Cum.
„ 303. *Terebra specillata*, Hds. "Probably two species here figured." San Blas, Mexico.
„ 303. *Terebra larviformis*, Hds. "Probably two species here figured." St. Elena, Monte Christi.
„ 307. *Terebra formosa,* Desh. Panama. Mus. Cum.
„ 307. *Terebra incomparabilis*, Desh. [= *T. flammea*, Lam., teste Rve., P. Z. S. 1860, p. 450]. Panama. Mus. Cum.
„ 308. *Terebra insignis,* Desh. Panama. Mus. Cum.
„ 428. *Spondylus Victoriæ*, Sby., pl. 49. fig. 8. Gulf of California. Mus. Cum.
„ 428. *Murex tæniatus*, Sby., pl. 49. fig. 3. Gulf of California. Mus. Cum.
1860 370. *Leda Taylori*, Hanl. Guatemala. Mus. Cum., Taylor.
„ 440. *Leda Hindsii*, Hanl. ? Gulf of Nicoya. Mus. Cum., Hanl., Metc.
„ 448–450. Review of Deshayes' 'Monograph of the *Terebridæ*,' 1859, by Mr. Reeve. His synonyms are quoted under par. 62, 'Conch. Ic.'
1862 239 5 *Bursa fusco-costata*, Dkr. California, Mus. Cum. [No authority.] Like *B. bituberculāris*, Lam.

* Many of the names given to the shells in Wood's Suppl. were arbitrarily altered by Dr. Goodall, as the work passed through the press (teste Gray). However, if the first *published*, they will be allowed the right of precedence.

In the P. Z. S. 1861, pp. 145–181, is the first part of the long-expected "Review of the *Vermetidæ*," by Otto A. L. Mörch. The species of the West Coast are arranged as follows:—

Page. Sp.
151 4. *Stephopoma pennatum*, Mörch, pl. 25. f. 3–8. } Realejo, on *Callopoma*
152 .. *Stephopoma pennatum*, ?var. *bispinosa*, pl. 25. f. 9, 10. } and *Crucibulum*.
153 5. *Siphonium* (*Dendropoma*) *megamastum*, Mörch, pl. 25. f. 12, 13. "?California; burrowing in *Haliotis nodosus*, Rve." [Not a Californian species.]
.. *Siphonium* (*Dendropoma*) *megamastum*, var. *centiquadra*, Mörch. "=*Aletes centiquadrus*, var. *imbricatus*, Maz. Cat. p. 302," Mörch [non Cpr.]. California, burrowing in *Haliotis splendens* [a strictly Californian species, not found on the Mexican coast].
154 6. *Siphonium* (*Dendropoma*) *lituella*, Mörch. California; deeply imbedded in *Haliotis splendens*; Mus. Cum.
?=*Stoa ammonitiformis*, M. de Serres.
=*Spiroglyphus*, sp., Cpr., B. A. Report, p. 324. [Found on shells from Washington Ter. to Cape St. Lucas (also Socoro Is., *Xantus*); but it has not been observed on the Mexican or Central American coast.]
161 20. *Siphonium margaritarum*, Val. Panama, *Val.*; Mazatlan, *Reigen*.
" =*Aletes margaritarum*, Maz. Cat. p. 303," [teste Mörch, non Cpr.*].
177 36. *Vermiculus pellucidus*, Brod. and Sby., pl. 25. f. 17–20.
.. .. Var. *a. planorboides* = *Serpula regularis*, Chenu. *Hab.* ?—, on ?*Margaritifera*. Mus. Cum.
.. .. Var. *aa. laquearis*. W. Columbia, *Cuming*.
178 .. Var. *β. cinnamomina*. W. Columbia, *Cuming*.
.. .. Var. *γ. volubilis*, Mörch, pl. 25. f. 18, 19. = *Vermetus eburneus*, Rve., = *V. lumbricalis*, Knight. *Hab.* ?—. Mus. Cum.
.. .. Var. *δ. volubilis* (*adulta*) *picta*, Mörch, = *Verm. eburneus*, Maz. Cat. p. 304. W. Columbia, *Cuming*; Puntarenas, *Oersted*, Journ. Conch. viii. p. 30.
.. .. Var. *ε. crassa*, Mörch, = *Serp. Panamensis*, Chen. Ill. pl. 10. fig. 5 = *Vermiculus eburneus*, Mörch, Journ. Conch. viii. 30. Puntarenas, *Oersted*. "Fossil at Newburn, N.C.," *Nuttall* [teste Mörch].
179 .. Var. *ζ. tigrina*, Mörch. W. Columbia, *Cuming*.
.. .. Var. *η. castanea*, Mörch. On *Murex melanoleucus*, Mörch.
.. .. Operculum: W. Columbia, *Cuming*.
.. .. Var. 1, from var. δ. = *Vermetus Hindsii*, Gray, Add. Gen. fig. ?8, *a*, *b*. Puntarenas, *Oersted*.
180 .. Var. 2, *discifer*, from var. δ. Puntarenas, *Oersted*.
.. .. Var. 3, from var. ε. Pl. 25. f. 17.
Var. 4, *subgranosa*, from var. η. Puntarenas, *Oersted*.
181 38. *Vermiculus effusus*, Val., = "*Vermetus e.*, Val." Chen. Ill. pl. 5. fig. 4, *a–c*. =*Siphonium e.*, Chen. Man. fig. 2301. "Fig. 4 of Chen.† is from specimen figured in Voy. Ven. as *V. centiquadrus*."

In the second part of Mörch's "Review of the *Vermetidæ*," 1861, pp. 326–365, occur the following. A portion of the genus *Bivonia* is united to *Spiroglyphus*. *Petaloconchus*, *Aletes*, and part of *Bivonia* are united to *Vermetus*, Mörch (non auct.). The name *Aletes* appears to be used in a varietal sense, in no respect according with the subgenus as described by the author.

* I was perhaps wrong in referring the Mazatlan shells to Val.'s species; but if Mr. Mörch is right in his own determination, the Mazatlan synonymy and locality must be expunged. There was no evidence of a typical *Siphonium* when the Reigen Catalogue was published, nor have I seen such from the whole coast, unless the minute operculum *h*, Brit. Mus. Col., tablet 2537, be supposed the young. Mörch says, "the lid is unknown." The operculum of the similar Mazatlan species, on which the subgenus *Aletes* was founded, is described in Maz. Cat. p. 302.

† "Cpr.'s observations respecting Chenu's plates (Maz. Cat. p. 306, lin. 18) are in part erroneous, it being overlooked that Chenu has two plates marked 'V.';" note *, p. 337.

Page. Sp.
332 8. *Spiroglyphus albidus*, ?Cpr. Mazatlan, *Reigen*. Operculum *g* et ?*f*, Maz. Cat. p. 311.=*Bivonia albida*, Cpr., Maz. Cat. p. 307. Operc. *g* is without doubt of *Spiroglyphus*, and not of *Bivonia*, var. *indentata*. Operc. *f* is truly congeneric, and perhaps conspecific.
344 4. *Vermetus* (*Thylacodus*) *contortus*, Cpr.* Gulf Calif. Mus. Cum.
.. .. Var. *α. repens* (*Thylacodus*). Gulf Calif., on *Margaritifera*, Mus. Cum. "This species is perhaps a state of *V.* (*Petaloconchus*) *macrophragma*." [Mörch: non Cpr.]†
345 .. Var. *β. favosa* (*Thylacodus*). Calif., on *Crucibulum*. Mus. Cum.
.. .. Var. *γ. contortula* (*Thylacodus*). Gulf of California.
.. .. Forma 1. ?*Thylacodus contortus*, var. *indentata*, Cpr. "Corresponds to forma 1, *electrina*, of *Vermetus varians*, D'Orb."
.. .. Var. *δ. indentata* (*Vermetus*), [Mörch, non Cpr.]. Sonsonate, on *Spondylus limbatus*, Rve., non Sby. *Oersted.*
346 .. Var. *ε. corrodens* (*Vermetus*). Is. Sibo (?Quibo), *Spengler*, on *Purpura lineata*.
359 20. *Vermetus* (??*Strebloceras*) *anellum*, Mörch. California, on *Haliotis tuberculatus*, Rve. [Not a Californian *Haliotis*. The diagnosis, however, exactly accords with a Californian shell, which is perhaps the young of *S. squamigerus*. It has no resemblance to *Strebloceras*, Cpr., P. Z. S. 1858, p. 440, which is a genuine Cæcid.]
360 21. *Vermetus* (*Macrophragma*) *macrophragma*. Mazatlan, &c.=*Petaloconchus m.*, Cpr. Realejo, *Oersted.*
362 24. *Vermetus* (*Aletes*) *centiquadrus*, Val. Puntarenas, *Oersted* + *V. effusus*, Val. (the same specimen).
.. .. Var. *α. maxima*= *V. Panamensis*, Chen. pl. 5. f. 1. Panama, *C. B. Ad.*; Mazatlan, *Melchers*.
.. .. Var. *β. Punctis impressis destituta*,= *V. Péronii*, Val.‡
363 .. Var. *γ. siphonata*. Puntarenas, *Oersted*= *V. Péronii*, Rouss.
.. .. Var. *δ. tulipa*. Gulf of California, on piece of black *Pinna*, Mus. Cum. [The *Pinna nigrina* is from the E. I.]= *V. tulipa*, Rouss.
.. .. Var. *ε. Bridgesii*. Panama, on *Margaritifera*, Mus. Cum.

The conclusion of the paper is in P. Z. S. 1862, pp. 54–83.

58 4. *Bivonia sutilis*, Mörch. Central America, on *Anomalocardia subimbricata*, Mus. Cum.
.. .. Var. *α.* ?*major*. On *Pinna*, probably Central America, Mus. Dunker.
.. .. Var. *β. triquetra*. Mazatlan, on valve of *Placunanomia*, Mus. Semper. Like *B. triquetra*, "var. *typica*."
70 8. *Thylacodes cruciformis*, Mörch. California, on *Crucibulum* ?*umbrella*, Desh., var. Mus. Cum. Analogue of 7, *T. Rüsei*, Mörch, from the east coast.
.. .. Var. *α. lumbricella*. Voy. Ven. pl. 11. f. 2. California, crowded on *Margaritifera*. Mus. Cum.
.. .. Var. *β. erythosclera*. Cal., on young *Margaritifera*. Mus. Cum. Very like *Biv. Quoyi, var. variegata*. [This species is on shells from the Mexican, not the "Californian" fauna.]
76 16. *Thylacodes squamigera*, Cpr.,=*Aletes sq.*, Cpr., P.Z.S. 1856, p. 226. Sta. Barbara, *Nutt.* [*Serpulorbis*, not *Aletes*, teste *Cooper*].

* Mr. Mörch has not seen any laminæ inside, but, from the 3–5 spiral liræ on the columella, believes they will be found. The opercula supposed to belong to this species (Maz. Cat. p. 311) Mr. M. thinks more probably those of *Spiroglyphus albidus*. He states (erroneously) that the shell was not opened by the describer.

† Mörch supposes that *Bivonia contorta*, Cpr., may be the adult of *Petaloconchus macrophragma*, and that both may be forms of *Aletes centiquadrus*. The nuclear portions are, however, quite distinct, and the three shells appear, from beginning to end, as far removed as any ordinary Vermetids can be from each other.

‡ The writer doubts respecting this species, and thinks the shell on which it is parasitical to be a *Melo*, and not *Strombus galea*, simply because named after Péron, who did not visit this district.

Page.	Sp.	
76	16	Var. *a. pennata*, = *V. margaritarum*, Val. Ven. pl. 11. f. 2. (fig. min.), Cal. Mus. Cum. [Affiliated to the Californian species on suppositious evidence, and probably distinct. These appear to be from the tropical fauna.] Analogue of the W. Indian *T. decussatus*, Gmel.
78	21.	?*Thylacodes oryzata*, Mörch. Probably W. Central America, from the adhesions; but "China:" Mus. Cum. .. ..
..	..	Var. *α. annulata*. Panama. Mus. Cum.*

In P.Z.S. 1861, pp. 229–233, is given a "Catalogue of a Collection of Terrestrial and Fluviatile Molluscs, made by O. Salvin, Esq., M.A., in Guatemala: by the Rev. H. B. Tristram." But few of the 49 species occur in Mexican collections; none are identical with W. Indian species, except such as are of universal occurrence in tropical America; and the 16 new species show close generic affinities with the shells of the northern regions of S. America. The shells have been identified from the Cumingian collection. The new species are described, and some of them figured.

Page.	No.	Pl.	Fig.	
230	1	..	..	*Helix Ghiesbreghti*, Nyst. The largest *Helix* in the New World.
..	2	..	..	*Helix eximia*, Pfr.
..	3	..	..	*Helix Lalliana*, Pfr., var.
..	4	..	..	*Helix euryomphala*, Pfr. Closely allied to the S. American *H. laxata*.
..	5	..	..	*Helix coactiliata*, Fér.
..	6	..	..	*Bulimus Pazianus*, D'Orb.
..	7	..	..	*Bulimus Moricandi*, Pfr.
..	8	..	..	*Bulimus Honduratianus*, Pfr.
..	9	..	..	*Bulimus Dysoni*, Pfr.
..	10	26	8.	*Bulimus semipellucidus*, n. s. Allied to *B. discrepans*, Sby.
..	11	..	..	*Succinea ?putris*, Ln.
..	12	..	..	*Glandina Ghiesbreghti*, Pfr.
..	13	..	..	*Glandina Carminensis*, Morelet. Described from Costa Rica.
..	14	..	..	*Achatina*, sp. ind.
..	15	..	..	*Achatina octona*, Lam.
..	16	..	..	*Spiraxis Lattrei*, Pfr.
..	17	..	..	*Spiraxis Shuttleworthii*, Pfr.
231	18	..	..	*Spiraxis Cobanensis*, n. s.
..	19	..	..	*Spiraxis*, sp. ind.
..	20	..	..	*Leptinaria Emmelinæ*, n. s.
..	21	..	..	*Leptinaria Elisæ*, n. s.
..	22	..	..	*Cylindrella Ghiesbreghti*, Pfr.
..	23	..	..	*Cylindrella Salpinx*, n. s.
..	24	..	..	*Physa Sowerbyana*, D'Orb.
..	25	..	..	*Physa purpurostoma*, n. s. Lake of Dueñas.
..	26	..	..	*Planorbis corpulentus*, Say.
232	27	..	..	*Planorbis tumidus*, Pfr. [Comp. *P. tumens*, Maz. Cat. 238.]
..	28	..	..	*Planorbis Wyldi*, n. sp. Lake of Dueñas.
..	29	..	..	*Planorbis Duenasianus*, n. s. Lake of Dueñas.
..	30	..	..	*Planorbis*, sp. nov., in Mus. Cum.
..	31	..	..	*Segmentina Donbilli*, n. s. Lake of Dueñas.
..	32	..	..	*Melampus fasciatus*, Chem. Salt-marshes on coast.
..	33	..	..	*Adamsiella Osberti*, n. s.

* The present posture of binomial nomenclature is well illustrated in this most elaborate paper, which few naturalists have professed to understand. The shell of which the operculum-spine is figured in plate 25. f. 16, is quoted as "*Siphonium* (*Stoa*) *subcrenatum*, v. *spinosa*." The shell described in Maz. Cat. p. 307 is quoted as "*Vermetus* (*Thylacodus*) *contortus*, var. γ. *contortula* (*Thylacodus*), *forma* 1, *Thylocodus* (?) *contortus*, var. *indentata*, Cpr." Perhaps the *sentences* of Klein and the early writers are more easy to understand and remember. The *Chitonidæ* of Middendorff (*v.* First Report, p. 214) are simple in comparison.

Page.	No.	Pl.	Fig.	
..	34	..	..	*Cistula trochlearis*, Pfr.
..	35	..	..	*Chondropoma rubicundum*, Morelet.
..	36	..	..	*Megalomastoma simulacrum*, Morelet. Described from Costa Rica.
..	37	..	..	*Cyclophorus ponderosus*, Pfr.
..	38	..	..	*Cyclophorus translucidus*, Sby.
233	39	26	11.	*Macroceramus polystreptus*, n. s.
..	40	26	9, 10.	*Helicina Salvini*, n. s. Like *H. turbinata*, Wiegm. Mexico.
..	41	..	..	*Helicina amœna*, Pfr.
..	42	..	..	*Helicina Oweniana*, Pfr.
..	43	..	..	*Helicina merdigera*, Sallé. Described from Nicaragua.
..	44	..	..	*Helicina Lindeni*, Pfr.
..	45	..	..	*Helicina chryseis*, n. s. Mountain forests of Vera Paz.
..	46,47,48	..	..	*Paludinella*, 3 species apparently undescribed.
..	49	..	..	*Pachycheilus corvinus*, Morelet. Larger than in previously noted habitats.

The vol. for 1863 contains Dr. Baird's descriptions of new species from the Vancouver collections of Lord and Lyall, which will be tabulated, *infrà*, par. 103; and the Review of Prof. Adams's Panama shells, which has already been quoted.

60. *Sowerby*, '*Conchological Illustrations*,' 1841.—The following are additional localities or synonyms:—

No.	Fig.	
2	46.	*Cardium Indicum* [is exotic; closely allied to *C. costatum*].
56	18.	*Cardium maculatum*, Sby. Cal., &c. $=$ *C. maculosum*, Sby. (preoc.).
90	..	*Murex imperialis*, Swains. Cal. $=$ *M. pomum*, var. Gmel. [Perhaps distinct; may be the W. I. analogue of *bicolor*.]
91	38.	*Murex erythrostoma*, Swains. Acapulco. [? $=$ *bicolor*, var.]
45	102.	*Cypræa albuginosa*, Gray. Mexico, Ceylon. [The Ceylon shell is probably *poraria*, sp. 44.]
1	45.	*Erato scabriuscula*, Gray. Acapulco. $=$ *Marginella cypræola*, Sby.
62	40.	*Fissurella Lincolni*, Gray, MS. [An extremely fine specimen (supposed "unique") of *Glyphis aspera*, Esch. Mr. Lincoln is also quoted for the "finest of the four known specimens" of *Lucapina crenulata*, sp. 19, f. 31, 38: "Monterey."]
54		[Erase this line in the former Report, and substitute as follows:—]
55		*Bulimus unifasciatus*, Sby. Galapagos.

'*Thesaurus Conchyliorum*,' G. B. Sowerby, &c. To the list in Rep. pp. 288, 289, may be added:—

Page.	Pl.	Fig.	
51	12	23.	*Pecten circularis*, Sby. Cal., St. Vincents. [The name may stand for the W. Indian shell, the Californian being *P. ventricosus*, jun.]
57	12	20, 21.	*Pecten latiauritus*, Conr. Cal. + "*P. mesotimeris*, Conr."
261	59	144.	*Tellina sincera*, Hanl. N.W. Coast America. [$=$ Panama.]
769	165	36–38.	*Venerupis cylindracea*, Desh. Cal., $=$ *Petricola Californica*, Conr., + *P. arcuata*, Desh., + *P. subglobosa*, Sby.
865	179	59–77.	*Cerithium ocellatum*, Brug. Gulf Cal., &c. $=$ *C. irroratum* [C. B. Ad. (Gld. MS.); non] Gld. E. E., $=$ *C. interruptum* [C. B. Ad.: non Mke, nec] Gld.

Sp.	Fig.	
47	43, 44.	*Conus** *interruptus*, Mawe, Wood. [Slender, coronated sp.] non Br. and Sby. *Hab.* ?—

* Mr. Sowerby remarks, "As the collector's great object is to *know* the shells, I have preferred, in most cases, giving the species as they stand, stating the alleged differences, and leaving the final decision to individual taste." He further states, with regard to some groups, that "the characters of the shells are very uncertain, and the intentions of the authors still more so." The names, references, and localities are given on lists to face the plates, and the diagnoses separately, with a copious index. An attempt also is made to

Sp.	Fig.	
64	80.	*Conus tiaratus,* Brod. Galapagos.
79	128, 129.	*Conus puncticulatus,* Brug. Salango, St. Elena, W. Col., *Cuming.*
..	130.	*Conus puncticulatus,* var., =*papillosus,* Kien.
..	391.	*Conus puncticulatus.* [Mazatlan.]
..	392.	*Conus puncticulatus,* var., =*pustulosus,* Kien. : ?+*Mauritianus,* Lam.
133	190.	*Conus virgatus,* Rve., =*zebra,* Sby., non Lam. [Resembles *regularis,* var.] Salango, W. Col., *Cuming.*
..	..	*Conus virgatus,* var., =*Lorenzianus,* Rve., non Chem.
..	193.	*Conus virgatus,* var., =*Cumingii.*
106	192.	*Conus scalaris,* Val., =*gradatus,* Rve. Salango, W. Col., *Cuming.*
127	194.	*Conus incurvus,* Brod. [Resembles specimens from La Paz.] Monte Christi, W. Col., *Cuming.*
180	285, 402.	*Conus Ximenes,* Gray, =*interruptus,* Brod., non Mawe. [Like *puncticulatus,* var.] Mazatlan, W. Columbia, *Cuming.*
157	324.	*Conus perplexus,* Sby. Gulf Cal., W. Col., *Cuming.*
84	384.	*Conus arcuatus,* Br. and Sby. Mazatlan, Pacific [?].
15	26–28.	*Fissurella Mexicana,* Sby. Real Llejos, Mexico. } [Both localities
..	78.	*Fissurella Mexicana,* Sby. Porto Praya. } are probably incorrect; it belongs to the Chilian fauna.]
41	46, 47.	*Fissurella rugosa,* Sby. W. Indies [=W. Mexico].
32	88, 89.	*Fissurella alba,* Cpr. [Gulf of] California.
55	64, 65.	*Fissurella nigrocincta,* Cpr. [Gulf of] California.
56	67.	*Fissurella tenebrosa,* Sby., jun. [?Gulf of] California. Like the last.
54	80.	*Fissurella obscura,* Sby. Real Llejos, *Cum.* ["Gal." in P.Z.S. 1834.]
68	154–156.	*Fissurella excelsa,* Rve., +*F. alta,* C. B. Ad.
86	123.	*Fissurella Panamensis,* Sby. "In Conch. Ill., this very distinct shell is united to that since named *F. excelsa,* Rve."
115	187–189.	*Fissurella cancellata,* Soland. St. Vincent's, Honduras Bay, Guadaloup, California. [No authority for the latter.]
7	12, 13.	*Harpa Rivoliana,* Less., =*H. crenata,* Swains. Acapulco.
1860.		
2	57.	*Dentalium pretiosum,* Nutt. "=*striolatum,* Stn. Massachusetts. Less curved and tapering near apex than *D. entale,* more cylindrical throughout, but a doubtful species." [The type-specimens are not striated.] California.
43	10.	*Dentalium hexagonum,* Gld. N. America: China, Singapore.
42	34.	*Dentalium pseudosexagonum,* Desh. Masbate, Philippines: W. Columbia.
8	41.	*Dentalium splendidum,* Sby. Xipixapi, W. Col.
29	32.	*Dentalium liratum,* Cpr. "Malgattem." [Maz. Cat. 244.]
48	31.	*Dentalium quadrangulare,* Sby. Xipixapi, W. Col. [Like *tetragonum,* but striated, and much smaller.]
49	21, 22.	*Dentalium tetragonum,* Sby. W. Col. [Young shell square, adult round.]

In the very elaborate monograph of the *Nuculidæ*, by S. Hanley, Esq., the following species, quoted as from the W. Coast, are minutely described:—

2	33.	*Leda Sowerbiana,* D'Orb. Xipixapi. =*N. elongata,* Val. =*N. lanceolata,* G. Sby., non J. Sby., nec Lam.
7	35.	*Leda Taylori,* Hanl., =*N. lanceolata,* Lam., non G. nec J. Sby. Guatemala. (P. Z. S. 1860, p. 370.)
29	70–72.	*Leda Elenensis,* Sby. Panama.
33	90.	*Leda eburnea,* Sby., =*lyrata,* Hds. Panama: Bay of Caraccas.

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classify the forms according to their natural affinities. It is rarely that monographers and artists take such laudable pains to supply the wants of students. In the monograph of *Galeomma* and *Scintilla,* however, the locality-marks have not been observed to a single species, except the "British *G. Turtoni*" and its "Philippine analogue, *G. macroschisma,* Desh." This is the more remarkable, as most of the species were described by Desh., with localities, in P. Z. S. 1855, pp. 167–181.

In the 'Malacological and Conchological Magazine,' by G. B. Sowerby, London, 1838, is a monograph of Leach's genus *Margarita*. The following probably belong to the N. W. Coast, and are figured in the Conch. Ill. :—

Page.
25. *Margarita striata*, Brod. and Sby. Boreal Ocean.
26. *Margarita undulata*, Sby. Arctic Ocean.
26. *Margarita costellata*, Sby. [Non Brit. Mus. Col. = *M. pupilla*, Gld.; differs in having the interspaces of the spiral ribs decussated. Arctic Ocean.]
26. *Margarita acuminata*, Sby. Arctic Ocean.
30. *Aphrodite columba*, Lea, = *Cardium Grœnlandicum*.

Several West Coast species were named and figured in the elder Sowerby's 'Genera of Recent and Fossil Shells,' London, 1820–1824; a work of singular merit for its time, but left unfinished*. The stock was purchased by a dealer, with a view to completion; but newer works have occupied its place, and the valuable plates and text remain useless in his hands. As no dates appear in the bound copy of the work, it cannot be stated whether the species here named by Mr. Sowerby had been before published. The loss of the original work has been in some respects supplied by the completion of the extremely similar 'Conchologia Systematica,' by L. Reeve, vol. i. 1841, vol. ii. 1842. It might almost be considered a second edition of the 'Genera,' of which some of the plates occur in the quarto form. References are here given to the species reproduced from Sowerby's unfinished work, which is often quoted by Mr. Reeve according to the "Numbers" in which it appeared:—

Rve. Fig.	Sby. Fig. Sowerby's Genera.
2.	2. *Cumingia trigonularis*.
3.	3. *Cumingia lamellosa*.
4.	4. *Cumingia coarctata*.
1.	1. *Tellina opercularis* ["= *T. operculata*, Gmel., = *T. rufescens*, Chem.," Rve.].
1.	1. *Lucina punctata* [Linn., "= *Lentilaria p.*, Schum." Rve. C. S.].
2.	2,5. *Venus subrugosa*.
5.	7. *Venus gnidia*.
2.	2. *Cytherea planulata*.
3.	3. *Cytherea aurantiaca*.
4.	4 [non 3]. *Lithodomus caudigerus* [Lam., = *aristatus*, Dillw.].
3.	3. [Appears to represent *attenuatus*, Desh.]
6.	6. *Modiola semifusca* [inside view; exactly accords with *Braziliensis*, Maz. Cat., but is not Lamarck's species, teste Hanl.].
2.	2. *Lima squamosa* [Lam.].
2.	2. *Ostrea Virginica* [Lam.].
1.	1. *Placunanomia Cumingii*. "Brought by Mr. Henry Cuming from the Gulf of Dulce, in Costa Rico."
1.	1. *Lottia gigantea*, Gray. Genus named in Phil. Trans. = *Patelloides*, Quoy and Gaim. ? South America. [The U. S. E. E. specimens were labelled "Valparaiso." It comes to us from many parts of the world, but is only known to live in Middle and Lower California. = *Tecturella grandis*, Cpr., B. A. Rep. 1861, p. 137.
	3. *Siphonaria Tristensis*. [The figure is singularly like the Vancouver species, *S. thersites*.]
2.	2. *Crepidula onyx*.
4.	4. *Crepidula aculeata*: "= *P. auricula*, Gmel."
	3. *Calyptræa ?extinctorium*. [Sby., non Lam. The non-pitted form of *imbricata*.]
	4. *Calyptræa spinosa*.

* The last Part (no. 34) appeared "March 31, 1831," many years after the previous issues; teste Hanl.

Rve. Fig.	Sby. Fig.	Sowerby's Genera.
	5.	*Calyptræa imbricata.* [The pitted form. Appears in C. S., f. 1, as "*C. rugosa*, Less."]
	7.	*Calyptræa ?spinosa*, var. [The flat, smooth form of *spinosa*. Appears in C. S., fig. 4, as "*C. cinerea*, Rve., P. Z. S. 1842," p. 50. On a log of wood floating off Cape Horn.]
	2.	*Bulla virescens.*
4.	1.	*Nerita ornata* [=*scabricosta*, Lam.].
2,3.	2, 3.	*Litorina pulchra*, = *Turbo p.*, Swains.
4.	4.	*Litorina varia.* Panama.
5.	5.	*Cerithium varicosum.*
9.	9.	*Cerithium Pacificum.* [Closely resembles *Potamis ebeninus.*]
1.	1.	*Fasciolaria aurantiaca* [with operc. (non Lam.) = *F. princeps*, Lam., Rve.].
	5.	*Murex phyllopterus* and operc. [Appears = *Cerostoma foliatum.* The operc. seems to have been rubbed outside.]
1.	1.	*Columbella strombiformis*, Lam.
2.	2.	*Columbella labiosa.* "California" [*i. e.*, Panama, &c.].
1.	1.	*Purpura patula* [Linn. "= *Perdicea nodosa*, Petiver, = *Cymbium tuberosum patulum*, Martini." Rve. C. S.].
6.	6.	*Purpura planospirata.*
9.*	9.	*Purpura callosa* [= *Cuma tectum*].
3.	3.	*Monoceros lugubre* [=*cymatum*, Tank. Cat.].
4.	4.	*Monoceros cingulatum* [Lam.: *Leucozonia*].
1.	1.	*Trichotropis bicarinata*, and [Nassoid] operculum.
1.	1.	*Oliva porphyria* [Linn., "= *Cylinder porphyreticus*, D'Arg., = *Castra Turcica*, Martini." Rve. C. S.].
	5.	*Cypræa pustulata* [Lam.].

The following additional West Coast species, figured in the 'Conch. Syst.,' may be quoted for their synonymy. The authorities for all the species are given, but no localities:—

Pl.	Fig.	
26	1.	*Solecurtus Dombeyi*, Lam. [appears intermediate between *S. Dombeyi*, Mus. Cum., and *S. ambiguus*, Lam.].
220	7.	*Turbo squamiger*, Rve. P. Z. S. 1842, p. 186 [without locality. 'Galapagos, *Cuming*,' in Conch. Ic. Also Acapulco, *Jewett*, &c.].
229	2.	*Turbinellus acuminatus*, Wood, Kien. [closely resembles *Latirus castaneus*].
268	3.	*Buccinum elegans*, Rve., P. Z. S. 1842, from Hinds's Col. [is the southern, highly developed form of *B. fossatum*, Gld. The name is preoccupied by a Touraine fossil, *B. elegans*, Duj., in Desh. An. s. Vert. x. p. 219, no. 22. As Rve.'s species is a *Nassa*, and there is another *Buc. elegans*, Kien., Coq. Viv. p. 56, pl. 24. f. 97, = *Nassa e.*, Rve. Conch. Ic., it will save confusion to allow Gld.'s later name to stand].
268	5,6.	*Buccinum serratum*, Dufr., = *Nassa Northiæ*, Gray [= *Northia pristis*, Desh.].

62. *Reeve*, '*Conchologia Iconica.*'—The following corrections should be made in the abstract, Rep. pp. 289–293.

20. [*Semele flavicans* should be *flavescens*, et *passim.*]
33. *Siphonaria amara* [is a Sandwich Is. species, quite distinct from *C. lecanium*].
38. *Patella clypeaster* [is a S. American species, having no connexion with *A. patina*, or with Monterey].
60. *Patella cinis* [= *A. pelta*, not *patina*, var.].
67. *Patella vespertina.* [*P. stipulata*, sp. 117, is probably a var. of this species.]
69. *Patella toreuma* ["var." in Mus. Cum., "Mazatlan," probably = *livescens*. No shell of this (N. Zealand) type has been found on the coast by any of the American collectors].

* Sowerby's (correct) name appears on Reeve's plate; but in the text of C. S., f. 9 is called "a species of *Turbinellus* inserted inadvertently."

81. *Patella Nuttalliana.* [Mus. Cum., = *A. pelta*, typical. The figure looks more like *patina.*]
140. *Patella mamillata,* Nutt. [non Esch., is an elevated, stunted form of the black ? var. of *scabra,* Nutt. The name being preoccupied, this distinct form may stand as *limatula*].
64. *Fissurella densiclathrata* [is distinct from *G. aspera.* Sta. Barbara, *Jewett*].
57. *Turbo marginatus* [Rve., non] "Nutt." [is a Pacific species, quoted by Messrs. Adams as the *Collonia marginata* of Gray; but that is a Grignon fossil, olim *Delphinula* (teste type in Brit. Mus.). The Nuttallian shell, published in Jay's Cat., was described by A. Ad. as *Chlorostoma funebrale* = *Chl. mœstum*, auct. (non Jonas, the true *T. mœstus* being S. American, teste A. Ad. and Mus. Cum.)].
39. *Cypræa onyx* [is the E. Indian, *C. spadicea* the similar S. Diegan species].

The following species, either quoted from the W. Coast, or known to inhabit it, or connected with it by synonymy, have been observed in Reeve's 'Conch. Ic.' since the date of the last Report. The number of the species also refers to the figure. For the remarks enclosed in [ ] the writer of this Report, here as elsewhere, is alone responsible.

56. *Fusus turbinelloides,* Rve., Jan. 1848. ?Africa, Mus. Cum. [= *Siphonalia pallida,* Br. and Sby.; spines somewhat angular].
62. *Fusus cancellatus,* Lam. "Unalaska, Kamtschatka, Mus. Cum." [Doubtless the origin of the prevalent locality-error].
70. *Fusus Novæ-Hollandiæ,* Rve., Jan. 1848. N. Hol., *Metcalfe.* [As Mr. Metcalfe gave numerous West Coast shells to Brit. Mus. under locality "N.H.," this shell also was probably from W. Mexico, = *F. Dupetithouarsii,* Kien.]
91. *Fusus Gunneri,* Lov., (*Tritonium*), Ind. Suec. p. 12. Greenland. [= *Trophon multicostatus,* Esch. The fig. should be 90, *b*; f. 91 = *Bamffius.*]
52. *Cardium pseudofossile,* Rve. "P. Z. S. 1844." *Hab.* ?— [Not found in P. Z. S., = *C. Californiense,* Desh., 1839, non *C. Californianum,* Conr., 1837. This is the Eastern form; the Californian ? var. = *C. blandum,* Gld.]
67. *Buccinum modificatum,* Rve., Dec. 1846. *Hab.* ?— [Agrees sufficiently well with worn specimens from La Paz, Mus. Smiths., = *Siphonalia,* closely allied to *pallida.*]
62. *Buccinum dirum,* Rve., Dec. 1846. *Hab.* ?— Mus. Cum. [Worn specimen of *Chrysodomus Sitchensis,* Midd., 1849, = *F. incisus,* Gld., May 1849.]
110. *Buccinum corrugatum,* Rve., Feb. 1847. *Hab.* ?— [" *Truncaria,*" Cuming, MS. " *Pisania,*" H. Adams. Vancouver, most abundant.]
2. *Sanguinolaria ovalis,* Rve., March 1857. Cent. Am. [? = *S. miniata,* jun. 3. *S. tellinoides,* A. Ad., is the same, adolescent; 5. *S. purpurea,* Desh., adult.]
4. *Psammobia maxima,* Desh., P. Z. S. 1854, p. 317. Panama. [Closely resembling *Ps. rubroradiata,* Nutt. Puget Sound.]
19. *Mytilus palliopunctatus,* Dkr. Cal. and Mazatlan. [No authority for Cal.]
41. *Mytilus bifurcatus,* Conr., J. A. N. S. Phil. *Hab.* ? [Conr. assigns his Nuttallian species to California; but it is the common Sandw. Is. species, teste Pse. The Californian shell, with the same sculpture, is a *Septifer,* and is the *S. bifurcatus* of Mus. Cum.]
44. *Mytilus Sallei* (*Dreissina*), Recl. Central America. [? On which slope.]
52. *Mytilus Cumingianus,* Recl. Panama. [*Septifer.*]
60. *Mytilus glomeratus,* Gld. *Hab.* ?—* [Gould's species is from California, but the name is attached to a very different shell in Mus. Cum.]

* Several species occur in the recent monographs without locality, which are well known to inhabit the W. Coast. This is partly due to the writer not thinking it necessary to refer to published books for information, and partly to the changes which have of late years been made in the principal authority, viz. the Cumingian collection. By the redistribution of species into the modern genera, the student is greatly aided in his search for special forms; but, for the sake of uniformity, the autograph labels of collectors or describers of species are generally rejected, the names being either in the handwriting of the clerk or from the printed index in the monograph, and representing only the judgment of the latest worker, which may or may not be correct. Synonyms, whether real

11. *Modiola capax*, Conr. Galapagos, *Cuming*. [Lower] California, *Nuttall*. Mazatlan, *Carpenter*. [*Reigen* is the authority for the shells described in the Maz. Cat., not Cpr.]
17. *Modiola Braziliensis*, Chem. "Brazil." [At f. 31, which appears the true Brazilian shell, we are informed that this specimen is a "variety from Guayaquil."]
.. *Modiola nitens*, "Cpr. Cat. Reigen Col. Brit. Mus. California." [The shell was erroneously described as from "California" in P. Z. S., and does not appear in the Reigen Mazatlan Cat.: = *M. subpurpureus*, Mus. Cum.]
5. *Lithodomus cinnamominus*, Chem. Philippine Is. and St. Thomas, W. I. [= *L. cinnamomeus*, Maz. Cat. 177. Probably an *Adula*.]
8. *Lithodomus Cumingianus*, Dkr., MS. "North Australia and Mazatlan." [The species is *figured* from the Mazatlan specimen, which may probably be the adult form of *L. calyculatus*, Cpr.* The cup is not distinct, but shows a tendency to the peculiar formation described in Maz. Cat. no. 174. Rve.'s diagnosis, however, appears written from Dkr.'s Australian specimens, so labelled in Mus. Cum.—a very distinct species, without incrustations. The name was given by Mr. Cuming to a large Chilian species brought by the U. S. Expl. Exp.]
12. *Lithodomus Gruneri*, Phil. MS. in Mus. Cum. "N. Zealand." [The species = *L. falcatus*, Gld., and is certainly from California, where it is found in the rocks with *Pholadidea penita*.]
13. *Lithodomus teres*, Phil. "Mazatlan." [The specimens in Mus. Cum. are labelled "Cagayan, *Phil.*"]
14. *Lithodomus coarctata*, Dkr. Galapagos, *Cuming*. [= *Crenella c.*, Maz. Cat. 172.]
16. *Lithodomus caudigerus*, Lam. "West Indies" [without authority]. "The calcareous incrustation produced beyond the ant. extremity is no specific characteristic." [*Vide* reasons for contrary opinion, Maz. Cat. no. 176: = *L. aristatus*. Dr. Stimpson has seen *Lithophagus* arranging its peculiar incrustation with its foot.]
24. *Lithodomus pessulatus*, Rve. (Oct. 1857). *Hab.* ?— [The unique sp. figured is labelled "Mazatlan" in Mus. Cum. It resembles *plumula*, with ventral transverse rugæ.]
26. *Lithodomus subula*, Rve. *Hab.* ?— [= *L. plumula*, var.]
6. *Avicula Cumingii*, Rve., March 1857. "Ld. Hood's Is., Pacific Ocean, attached to rocks, 10 fms., *Cuming*." [? = *Margaritiphora fimbriata*, Dkr., var.]
9. *Avicula barbata*, Rve. Panama, under stones at low water, *Cuming*. [= *M. fimbriata*, Dkr., = *M. Mazatlanica*, Hanl.] "Differs from *Cumingii* in regular sequence of scales, developed only at margin, and yellowish tone of colour."
67. *Avicula heteroptera*, Lam. N. Holland. " = *A. sterna*, Gld." [Gould's species is from Gulf Cal.; but in Mus. Cum. it is marked inside "*semisagitta*."]
4. *Placunanomia foliata*, Brod. Is. Muerte, Bay Guayaquil. "May = *echinata*, W. I., but has very much larger orifice."
7. *Placunanomia macroschisma*, Desh. "Onalaska, *Cuming*" [who never was there]. Kamtschatka, *Desh.* [Vancouver district, abundant.]
7. *Thracia plicata*, Desh. "Mr. Cuming has specimens from California and St. Thomas, W. I." [Cape St. Lucas, *Xantus*.]

Melania. [Various species are described from "Central America," &c., which

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or supposed, are rejected altogether. Thus shells sent to Mr. Cuming, with authentic name and locality attached, may appear soon after without any, or with erroneous, quotation. The error is rendered graver by appearing with the weighty authority of "Mus. Cum."

* The species described in the Brit. Mus. Cat. seldom appear in the monographs, unless there happen to be a specimen in Mus. Cum. Some of the monographers often content themselves with figuring the shells that come most easily to hand; and do not seem to consider it a part of their work to pass judgment on previously described species, or to concern themselves with what are small or difficult.

may or may not belong to the Pacific slope. They should be studied in connexion with U. S. forms, but are not here tabulated.]

50. *Melania Buschiana*, Rve. "California." [No authority. Very like the young of *M. scipio*, Gld.]

367. *Melania nigrina*, Lea, MS. in Mus. Cum. "Shasta, California."

68. *Cancellaria funiculata*, Hds., = *C. lyrata*, Ad. and Rve. Gulf Magdalena.

56. *Litorina irrorata*, Say. "Sitcha." [The "Sitcha" shell is *L. modesta*, Phil. Say's species is the well-known form from the Gulf of Mexico.]

5. *Terebra strigata*, Sby., + *elongata*, Wood., = *flammea*, Less., = *zebra*, Kien. "Panama, Galapagos, and Philippines, *Cuming*; Moluccas, &c." [Painting in stripes.]

10. *Terebra robusta*, Hds. Panama, &c. [= *T. Loroisi*, Guér., teste Rve. P. Z. S. 1860, p. 450. Painting splashed.]

12. *Terebra variegata*, Gray. "Mouth of the Gambia, Senegal, Mazatlan, Columbia. It is well known to those who have studied the geographical distribution of animal life, that the fauna of the West African seas, north of Sierra Leone, is in part identical with the fauna of the seas of California and the W. Indies; and geologists, among whom was the late Prof. E. Forbes, have laboured, not unsuccessfully, to account for this phenomenon." [*Vide* Maz. Cat. p. 157, B. A. Rep. p. 365. In the present instance, however, there will be more than one opinion as to the identity of the species here quoted.] + *T. africana*, Gray, + *T. Hupei*, Lorois, + *T. intertincta*, Hds., + *T. marginata*, Desh., + *T. albocincta*, Cpr., + *T. Hindsii*, Cpr., + *T. subnodosa*, Cpr.

72. *Terebra armillata*, Hds. "Panama, Galapagos. Somewhat doubtful whether this is not a var. of *T. variegata*." [If the others are, probably this is. Those species of Hinds, which Mr. Reeve has not altered, are not here repeated.]

32. *Terebra dislocata* [as *Cerithium*], Say. "Southern U. S. and California." [No authority given for Cal.]

34. *Terebra rudis*, Gray, " = *M. rufocinerea*, Cpr. S. Carolina, *Jay*. Somewhat doubtful whether this is not a var. of *dislocata*." [The *T. rufocinerea* is one of the difficult Mazatlan shells, and should share the fate of *T. Hindsii* and *T. subnodosa*.]

35. *Terebra cinerea*, Born. "W. Africa, *Hennah*; Japan, *Hds.*; Philippines, *Cuming*; W. I., *C. B. Adams*; Mazatlan, *Cpr.*" [i. e. *Reigen*. The same remarks apply to this group as to *variegata*, &c.] + *T. castanea*, Kien., non Hds., + *T. laurina*, Hds., + *T. luctuosa*, Hds., + *T. stylata*, Hds., + *T. Jamaicensis*, C. B. Ad.

40. *Terebra aspera*, Hds., + *T. Petiveriana*, Desh. Panama, S. A., *Cuming*, *Bridges*.

2. *Calyptræa tortilis*, Rve. Galapagos, *Cuming*.

8. *Calyptræa alveolata*, A. Ad., MS. Galapagos, *Cuming*.

4. *Crepidula excavata*, Brod. Chili [?], *Cuming*.

6. *Crepidula nautiloides**, Less., MS. in Mus. Cum. "New York." [= *C. dilatata*.]

8. *Crepidula marginalis*, Brod. Panama, *Cuming*. [V. Maz. Cat. p. 292, note.]

10. *Crepidula rugosa*, Nutt. Upper Cal. [An accidentally ribbed specimen, figured from Mus. Taylor.]

11. *Crepidula fimbriata*, Rve. (June 1859). Vancouver's Straits. [This is to *navicelloides*, Nutt., no. 97, as *Lessonii* is to *squama*; simply an accidentally frilled var.]

12. *Crepidula adunca*, Sby. [Not] Panama. = *C. solida*, Hds., = *rostriformis*, Gld. [This is the northern species from Vancouver and Cal., and is not] = *uncata*, Mke.

13. *Crepidula arenata*, Brod. St. Elena (not Helena, *Desh.*), *Cuming*.

22. *Crepidula aculeata*, Gmel. Lobos Is., Peru, *Cuming*; California, *Nutt.*, *Cpr.* [*i. e.* Mazatlan, *Reigen*]; Honduras, *Dyson*; Sandw. Is., Austr., Kur-

* Several S. American forms are here quoted for the synonymy; because in *Calyptræidæ* the species often have a wide range, and should be studied in connexion with their neighbours.

rachee, mouth of Indus. + *C. hystryx*, Brod., + *C. echinus*, Brod., + *C. Californica*, Nutt.

24. *Crepidula rostrata*, C. B. Ad. Panama. [= *C. uncata*, Mke., nom. prior. This tropical form presents distinctive marks.]
28. *Crepidula exuviata*, Nutt. Monterey. [= *C. explanata*, Gld., = *C. perforans*, Val. An abnormal form of *C. navicelloides*, Nutt.: *C. nummaria*, Gld., is the opposite extreme.]
29. *Crepidula bilobata*, Gray [*i. e.* Cpr.], MS. in Mus. Cum. [= *C. dorsata*, Brod. *Vide* Maz. Cat. no. 336, where the origin of the MS. name would have been found explained. It appears to be principally a northern species = *C. lingulata*, Gld.]
30. *Crepidula lirata*, Rve. [Gulf of] California. [Intermediate form between *C. incurva* and *C. onyx*, described in Maz. Cat. p. 277.]
2. *Crucibulum scutellatum*, Gray. "= *C. rugosa*, Less., = *C. imbricata*, Sby., non Brod." Payta, *Less.*; Punta St. Elena, *Cuming*. [*Vide* Maz. Cat. no. 343.]
4. *Crucibulum rugosum*, "Desh., non Less., = *C. lignaria*, Brod., ? var. = *C. gemmacea*, Val." Island of Chiloë, *Cuming*. [*Vide* Maz. Cat. p. 290.]
5. *Crucibulum ferrugineum*, Rve. Bay of Conception, Chili, *Cuming*. [= *C. quiriquina*, Less., D'Orb., = *C. Byronensis*, Gray, in Brit. Mus. Like a rough degraded form of *C. spinosum*.]
6. *Crucibulum umbrella*, Desh. = *C. rudis*, Brod. Panama and Real Llejos.
8. „ *corrugatum*, Cpr. "Cal." [Mazatlan, *Jewett*, P. Z. S. 1856, p. 204.]
9. „ *imbricatum*, Brod. Panama. [= *C. imbricatum*, Sby., = *C. scutellatum*, Gray, no. 2, var.]
10. *Crucibulum spinosum*, Sby. Seas of Central America. [Extends northwards to California; southwards it degenerates into *C. quiriquina*.] = *C. peziza*, Gray, + *C. hispida*, Brod., + *C. maculata*, Brod., + *C. tubifera*, Less., + *C. cinerea*, Rve.
11. *Crucibulum pectinatum*, Cpr., P. Z. S. 1856, p. 168. Peru. [Panama, *Jewett*.]
17. „ *auritum*, Rve., = *C. striata*, Brod., non Say. Valparaiso, *Cuming*. [Passes into *Galerus*.]
21. *Crucibulum serratum*, Brod. Real Llejos and Muerte, *Cuming*. [Like young of *C. pectinatum*; nearly transparent; white, with purple ray.]
22. *Crucibulum sordidum*, Brod., + *C. unguis*, Brod. Valparaiso and Panama, *Cuming*. [= *Galerus*; v. Maz. Cat. p. 292, note. The author distributes the species of this genus between *Trochita* and *Crucibulum*.]
4. *Trochita aspera* [Rve. as of] C. B. Ad. Panama. [The small var. of *Galerus conicus*. Probably = *C. aspersa*, C. B. Ad., no. 331.]
7. *Trochita subreflexa*, Cpr., MS. in Mus. Cum. Gulf of California. [= *Galerus subreflexus*, Cpr. in P. Z. S. 1855, p. 233.]
9. *Trochita corrugata* [?cujus. Comp. *Calyptræa corrugata*, Brod.]. Callao, *Cuming*.
8. *Trochita spirata*, Fbs. "? = *P. trochiformis*, Chem." Gulf California. [*Vide antea*, p. 542.]
10. *Trochita solida* [?Rve.]. Conchagua, Mus. Cum. [? = *Galerus mamillaris*.]
11. *Perna anomioides*, Rve. March 1858. California, Mus. Cum. [No authority; appears = *P. costellata*, Conr., Sandwich Islands.]
13. *Perna Californica* [Rve., non] Conr. California, *Conr.* [i. e. *Nutt.*] Honduras, *Dyson*. "Distinguished by the *Pedum*-like form and clouded, livid purple colouring. [This is the well-known large flat West Indian species; not known in California.]
3. *Umbrella ovalis*, Cpr. Mouth of Chiriqui River, Bay of Panama, [not] *Cuming* [but *Bridges*. The species was also found at Cape St. Lucas by *Xantus*.]
6. *Ianthina fragilis*, Lam., = *I. striulata*, Cpr. West Indies, Mazatlan, California. [*Vide* Maz. Cat. no. 242: non *I. striolata*, Ad. and Rve.]
19. *Ianthina decollata*, Cpr. Probably = *I. globosa*, var. [Maz. Cat. no. 243. Of the two Maz. forms, provisionally named, this appears the least entitled to specific rank.]
40. *Columbella Bridgesii*, Rve. April 1858. Panama, *Bridges*. [Appears the small var. of *C. major*.]
43. *Columbella Boivini* [= *Boivinii*, Kien.]. Gulf Nicoyia, *Hinds*.

46. *Columbella acicula,* Rve. California. [No authority.]
56. *Columbella encaustica,* Rve. Gulf California, *Lieut. Shipley,* Mus. Cum.
57. *Columbella vexillum,* Rve. Gulf California. [No authority.]
62. *Columbella cribraria,* Quoy and Gaim. [i. e. Lam.] = *C. guttata,* Sby. Panama, common under stones, *Cuming.* [No other localities given. V. *Nitidella cribraria,* Maz. Cat. no. 613.]
72. *Columbella electroides,* Rve. Bay of Guayaquil.
74. *Columbella Pacifica,* Gask. Galapagos.
109. *Columbella pusilla,* Sby. Island of St. Vincent, W. I. "= *Nitidella Gouldii,* Cpr." [The *Nitidella* is a distinct Upper Californian species.]
120. *Columbella lactea,* Rve. Gulf Calif., *Mr. Babb, R.N.* [A *Nitidella,* so transparent that the axis can be seen throughout.]
122. *Columbella Sta-Barbarensis,* Cpr. Sta. Barbara. "Not merely faintly striated, teste Cpr., but unusually grooved." [Described from a worn specimen in Jewett's Col., and named to mark a more northern limit to the genus than had been assigned by Forbes. The label was probably incorrect, as the shell lives in the tropical fauna, C. S. Lucas, *Xantus*: Acapulco, *Newberry*; Guacomayo, Mus. Smiths. The name (as expressing error) should therefore be altered to *C. Reevei,* Cpr.]
123. *Columbella spadicea,* Phil., MS. in Mus. Cum. Mazatlan. [Described by Phil. in Zeit. f. Mal. 1846: B. A. Rep. p. 225.]
130. *Columbella venusta,* Rve. [Mazatlan, *E. Philippi.*] = *C. tæniata,* Phil. [in Zeit. f. Mal. 1846], not Ad. and Rve., [Voy. Samar. 1850; therefore Phil. has precedence. ? = *Anachis Gaskoinei,* Maz. Cat. no. 652. The Samarang shell is probably a *Nitidella.*]
132. *Columbella sulcosa,* Sby. Annaa and Ld. Hood's Islands*. *Cuming.*
135. *Columbella Gouldii,* Agass., MS. in Mus. Cum., Nov. 1858. [= *Amycla Gouldiana,* Agass., Atlantic; non *Nitidella Gouldii,* Cpr.]
142. *Columbella uncinata,* Sby. Is. Muerte, Bay Guayaquil. [Acapulco, *Jewett.*]
165. *Columbella Californica,* Rve. April 1859. California. [No authority. Like *Anachis lirata.*]
176. *Columbella rorida,* Rve. Lord Hood's Island*, *Cuming.* [Transparent, glossy, with necklace of opake white dots.]

Genus *Meta* [= *Conella,* Swains, eliminated by Rve. from *Columbella*; but *Anachis, Strombina, Amycla* (pars), and *Nitidella,* which do not even belong to the same family, if the opercula are to be trusted, are left in the old place. Of the six species, the author only knew the locality for one], *M. Dupontiæ,* Kien.—Ichaboe, South Africa; [but that of] *M. ovuloides,* "C. B. Ad., MS." [is shown by his published works to be Jamaica; and the following are from the West Coast].

3. *Meta cedonulli,* Rve. [La Paz, Mus. Smiths.; C. S. Lucas, *Xantus*; Panama, *Jewett.*]
4. *Meta coniformis,* Sby. [? Panama, *Jewett.*]
24. *Ziziphinus luridus,* Nutt., MS. in Mus. Cum. California. [Is not known from the American coast; comp. Sandwich Islands.]
25. *Ziziphinus eximius,* Rve., P. Z. S. 1842. Panama, sandy mud, 10 fms. [= *T. versicolor,* Mke., 1850, = *Z. Californicus,* A. Ad., 1851. Scarcely differs from "*Javanicus,* Lam.," in Mus. Cum. The form was dredged by Mr. A. Adams in the eastern seas.]
31. *Ziziphinus Antonii,* Koch, in Phil. Abbild. pl. 1. f. 4. Australia. [Scarcely differs from the shouldered var. of *Calliostoma lima* (Phil.) C. B. Ad., which is called *eximius,* Rve., in Brit. Mus. Col.]
23. *Trochus Japonicus,* Dkr., [represents *Pomaulax undosus* on the east side].
24. *Trochus digitatus,* Desh. Distinct from *unguis,* with base like *gibberosus.* Central America. [Mr. Reeve's distinct shell is perhaps not that of Desh., and not from the West Coast.]
26. *Trochus undosus,* Wood, = *T. gigas,* Anton. California †.

* *Vide* Report, 1856, p. 168, note §§.

† Mr. Reeve states that, although this species is most like *gibberosus,* "Messrs. Gray and Adams contrive to place them in different genera." It is still more remarkable that, while

39. *Trochus auripigmentum*, Jonas. Panama. [Probably not from W. America.]
17. *Phasianella perforata*, Phil. Mazatlan, Panama + *Ph. compta*, Gld.* Rather out of place †; has neither form nor texture of *Phasianella*. [The aberrant form is due to the figured specimen being quite young; the adults in Brit. Mus. Col. prove the texture, colouring, and operc. to be normal.]

Genus *Simpulopsis*. This group, intermediate between *Vitrina* and *Succinea*, is stated to be peculiar to Brazil and Mexico, where *Vitrina* is not known.

In the Monograph of *Terebratulidæ*, which is prepared with unusual care, and the general introduction to which is well worth attentive perusal by all students, occur the following species which bear upon the West Coast fauna or synonymy:—

2. *Terebratula* (*Waldheimia*) *dilatata*, Lam., = *T. Gaudichaudi*, Blainv. "Str. Magellan," teste Gray, in Brit. Mus. Cat., without authority. [The E. E. specimens varied considerably in outline; and according to Darwin, and what we know of the variations of fossil species, it is quite possible to believe that this and the next species had a common origin. The great development of this most interesting form in the cold regions of South America is extraordinary.]
3. *Terebratula* (*Waldheimia*) *globosa* (Val.), Lam., from type. = *T. Californica*, Koch. "California, Coquimbo. Californian form well known; small specimen in Mus. Taylor, marked 'de Coquimbo.'" [There appears no authority for the general belief that this fine species is Californian. It was taken in abundance by the naturalists of the U. S. E. E. at Orange Bay, Magellan. The Californian shell, which is probably the original *Californica*, Koch. (not of authors) is a distinct species, teste Rve. from Dr. Cooper's specimens.]
7. *Terebratula* (*Terebratulina*) *radiata*, Rve., Mus. Cum. ? Straits of Corea, *Belcher*. [Very like the adult of *T. caurina*, Gld.]
11. *Terebratula uva*, Brod. Bay of Tehuantepec, Guatemala; 10–12 fms. sandy mud, on dead bivalve, *Capt. Dare*. Mus. Cum. and De Burgh. [The analogue of *T. vitrea*, Med.]
16. *Terebratula* (*Terebratulina*) *Japonica*, Sby., = *T. angusta*, Ad. and Rve. Corea, Japan. "Represents *T. caput-serpentis*, and probably the same."
23. *Terebratula physema*, Val., MS. (unique), Coquimbo. *Gaudichaud*, 1833. May be a colossal, broadly inflated var. of *globosa*.
6. *Orbicula Cumingii*, Brod. [Besides information in Rep. pp. 183, 244, is given] Is. Caña, Guatemala; sometimes 6–18 fms., *Cuming*. *O. strigata*, Brod., is a less-worn state of this species. [The type-specimens of *Discina strigata* in Brit. Mus., on *Pecten ventricosus*, appear very distinct, and are unusually shelly for the genus.]

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excluding *Ziziphinus* (= *Calliostoma*), Mr. Reeve "contrives to place" in *Trochus* animals shown by the opercula to belong to different subfamilies, as though we knew no more than in Lamarck's days; his motley group containing *Imperator* (= *Stella*, H. and A. Ad.) + *Lithopoma* + *Guildfordia* + *Chrysostoma* + *Bolma* + *Modelia* + *Polydonta* + *Tectus* + *Pomaulax* + *Astralium* + *Pachypoma* + *Uvanilla*. Also in a family the genera and species of which are mainly recognized by the base and mouth, most of the shells are only figured on the back. Very often the characters of the aperture are not even stated. Remarkable liberties are, moreover, sometimes taken with geographical facts, to the great astonishment of Americans, who expect even their schoolboys to avoid such statements as at sp. 57, *Tr. diminutivus*, Rve., "Oahu Islands;" and at sp. 1, *Lingula ovalis*, Rve., "from W. H. Pease, Esq., residing at Honolulu, one of the Sandwich Islands."

* *P. compta* is a distinct Californian species; its ?varieties pass into *pulla*. If Mr. Reeve can be followed in uniting to *pulla*, *pulchella*, Recl.; + *affinis* + *tessellata* + *pulchella* + *concinna*, C. B. Ad.; + *tenuis*, Phil.; + *intermedia*, Scacchi; + *Capensis*, Dkr.; + *elongata*, Krauss, Gould's species should join this goodly company, rather than *perforata*. The same standard of union followed among the large shells would greatly lessen the size of this costly work.

† So is *Phasianella rubra*, Pease MS., sp. 18, which belongs to *Alcyra*, A. Ad.; allied to *Euchelus*.

7. *Orbicula ostreoides*, Lam.,= *O. Norvegica*, Sby. (non Lam.) + *O. striata*, Sby. + *Crania radiosa*, Gld. + *O.* [*Discina*] *Evansii*, Dav. ? N.W. Africa. "The locality, 'Bodegas, Cal.,' given by Mr. D. with *O. Evansii*, on Mr. Cuming's authority, must, I think, be a mistake." [The genus has not been found on the Californian coast by any American collector.]
8 *Venus* * *grata*, Sby.,+*tricolor*, Sby. Gulf of Mexico, Mus. Cum. [= *Tapes grata*, Say, Panama. The locality-labels have probably been misplaced. These specimens are undoubtedly from the West Coast, nor has any authority appeared for the species in the Atlantic. The Gulf of Mexican "analogue" is *T. granulata*. The forms are intermediate between *Chione* and *Tapes*.]
9. *Venus multicostata*, Sby. Bay of Panama, in coarse sand at low water, *Cuming*. "Probably = *V. Listeri*, var., with ribs more tumidly thickened and rounded." [The West Coast shells are distinguished by the very slight crenulation of the ribs at the sides.]
19. *Venus asperrima*, Sby. Guacomayo, Centr. Am., sandy mud, 13 fms., *Cuming*. "A form of *pectorina*; shell of lighter substance, broader and more depressed; sculpture more elevately and definitely latticed." [This is the shell named by Mr. Cuming *V. cardioides*, Lam., and should take that name, as prior to Sby.'s, if really distinct from *pectorina*. Also from Panama. Mus. Smiths.]
22. *Venus discors*, Sby., jun. St. Elena and Guacomayo, Centr. Am., sandy mud, 6–9 fms., *Cuming*. "Concentric decussating ridges cease abruptly at the posterior third." [Character very variable, even in the type-specimens; = *T. grata*, Say, var.]
25. *Venus pectorina*, Lam., p. 344, + *V. cardioides*, Lam. Centr. Am., Mus. Cum. [Probably Atlantic; much heavier and stumpy; sculpture coarser; teeth more like *casina*, whereas *cardioides*, no. 19, has a long anterior tooth like *sugillata* †.]
26. *Venus cingulata*, Lam.,=*pulicaria*, Brod. W. Columbia, *Cuming*. [= *V. Pinacatensis*, Sloat, MS. in Mus. Smiths. Guaymas. The peculiar smoothing-off of the central sculpture in the adult may be varietal. It is improbable that Lam. was acquainted with the species.]
33. *Venus crenulata*, Chem.,=*crenata*, Gmel. W. I. = *V. eximia*, Phil.,+ *V. crenifera*, Sby.,+ *V. Portesiana*, D'Orb. [Not to be confounded with the *V. crenifera*, Maz. Cat.: has a small Cyprinoid lateral tooth, but no radiating ribs near lunule, nor long anterior tooth †.]
35. *Venus Californiensis*, Brod.,= *V. leucodon*, Sby. Guaymas, Gulf Cal., sandy mud, low water, [teste] *Cuming*. Mus. Cum. [= *V. crassa*, Sloat, MS. in Mus. Smiths. Not *V. Californiana*, Conr.,= *V. simillima*, Sby. This species, with *V. neglecta, compta*, &c., having the mantle-bend nearly obsolete, approach *Anomalocardia subimbricata*, and with that species form a natural group, differing from the typical *Venus* as *Lioconcha* does from *Callista*: = *V. succincta*, Val.]
41. *Venus Kennerleyi*, Cpr., MS. ‡ in Mus. Cum. *Hab.*—? [Puget Sound, *Kennerley*.]
43. *Venus sugillata*, Rve. California, Mus. Cum. Characterized by the shining purple umbos, finely latticed sculpture, dark-stained lunule and ligamentary area. [= "*V. crenifera*, Sby., teste Rve.," Maz. Cat. no. 105, in all essential characters. Differs in the long anterior tooth being still

* Through the kindness of Mr. Reeve, with a view to the completion of this Report, I was enabled to compare the figured specimens in this genus with the text, and with the shells of the Smithsonian collection, before they were distributed. The bracketed notes in the text are based on this examination. They are given with unusual detail, because of the unique opportunity of throwing some light on a confessedly difficult family.

† The characters of the teeth and pallial line frequently afford satisfactory diagnostic marks between critical species, which are often overlooked by monographers.

‡ The descriptions of Dr. Kennerley's shells had long been written, and would have been published but for the American war. The localities of all the West Coast shells sent from the Smiths. Col. to Mr. Cuming were duly marked in the accompanying catalogues.

longer, and in the purple colour. This, however, in the figured specimen, has been brought-out by the free use of acid, and the markings have been considerably obliterated by the "beautifying" process.]

44. *Venus simillima*, Sby. San Diego, Cal. "Resembles *V. compta* in detail of sculpture" [but perfectly distinct, belonging to the *amathusia* group. It shows the evil of the very brief diagnoses of the earlier conchologists that so discriminating an author as Mr. Conrad should have taken this shell for the *V. Californiensis*, Brod.; and, quoting it (*lapsu*) as *V. Californiana*, redescribed the true *V. Californiensis* as *V. Nuttallii*. It is known by the great closeness of the fine sharp ribs.]

46. *Venus*=*crenulata*, no. 33, very distinct var. Gulf Cal.; more globose, interior purple rose. [This was sent as "Cape St. Lucas, *Xantus*." It appears truly distinct from the W. I. *crenulata*, and to be the normal form of which *pulicaria*, no. 26, is an extreme var. Inside, and outside in the adolescent state, they agree exactly; differing outside, in the adult, in smoothed-off ribs and more distinct V-markings. Mr. Reeve, however, still thinks it more like *crenifera*. It may stand as "? var. *lilacina*."]

47. *Venus gibbosula*, Desh., MS. in Mus. Cum. *Hab.* ?— [Guaymas: = *V. Cortezi*, Sloat. This is the more rounded and porcellanous form of *V. fluctifraga*, = *V. Nuttalli* of Brit. Assoc. Report, and Nuttallian paper in P. Z. S. 1856, p. 21; but not the true *V. Nuttalli*, Conr., v. *infrà*, no. 49. Interior margin very finely crenated on both sides of the hinge.]

48. *Venus compta*, Brod. Bay of Sechura, Peru, coarse sand and mud, 7 fms., *Cuming*. [This rare species seems to represent *V. Californiensis* in the South American fauna. It is well distinguished by its shouldered form, produced ventrally, and by the Circoid pallial line, far removed from the margin. Guacomayo, Mus. Smiths.]

49. *Venus Nuttalli*, Conr. California. [Named from type, teste Conr. ips., v. *anteà*, p. 526. This is the dull northern form of *V. succincta*, as *fluctifraga* is of *gibbosula*, the species appearing nearly in the same parallels in the Gulf and on the Pacific coast, but not found in the Liverpool Reigen Col.; nor at Cape St. Lucas. In all essential characters, *Nuttalli* (though pointed) and *Californiensis* (though rounded) appear the same; but Mr. Reeve still thinks otherwise. The figured specimen has been altered with acid. The *V. excavata* is not noticed by Mr. R.]

51. *Venus mundulus*, Rve. *Hab.* ?— [This shell was obtained by Dr. Stimpson in the N. P. Expl. Exp., and bears the Smiths. Cat. number "1845. San Francisco, very common at low water," = *Tapes diversa*, Sby. jun. This is the highly painted, finely sculptured state of *T. staminea*, Conr. (not "*T. straminea*, Conr." Sby., = *T. grata*, var.) The abnormally ridged form is *V. ruderata*, Desh. Conch. Ic. sp. 130. By its large pallial sinus and bifid teeth it is a true *Tapes*.]

52. *Venus intersecta*, Sby. Puerto Puero [? Portrero], Centr. Am., *Cuming*. [The shell is exactly identical with no. 19, *asperrima*=*cardioides*; but the figure might mislead, the colour-lines appearing as ribs.]

54. *Venus subrostrata*, Lam.* vi. p. 343, = *V. neglecta*, [Gray] Sby. *Hab.* Mazatlan and West Indies. "Lam. having cited a figure of the China species, *V. Lamarckii*, the species was lost sight of till Sby. renamed it." [The *Lamarckian* species was probably West Indian. *V. neglecta* closely resembles the young of *V. Californiensis*, but has the ligamental area smooth only on one valve, instead of both.]

59. *Venus Stutchburyi* (Gray), Wood, Sandwich Is. Comes very near to the Californian *V. callosa*, [Sby., non] Conr., of which specimens have been found also at the Sandwich Is. [*V. Stutchburyi* is the New Zealand species, which may easily be confounded with the Californian. Although both may be *obtained* at the Sandwich Is., there is no evidence that either

* In critical species, when it is impossible to be positive which of two or more was intended by an old author, it appears best to retain the name of the first *discriminator*. The old name belongs to the general form: the discriminator ought to retain it for a part; but if that has not been done, it avoids confusion to drop it.

lives there. The shell here figured is beaked like *Nuttalli*, no. 49; lunule very faint; concentric ridges very faint, but sharp; radiating ribs very coarse. Inside deeply stained; margin not crenated on the sharp anterior edge, though faintly on the lunule; hinge-teeth stumpy.]

60. *Venus muscaria*, Rve. *Hab.* ?— [Has the aspect of a West Coast species, between *cardioides* and fine var. of *staminea*; sinus large; teeth strong, not bifid; lunule with radiating ribs.]

68. *Venus undatella*, Sby. Gulf Calif. [Not a satisfactory species, the type having the aspect of a poor specimen altered for cabinet. The "sculpture much changing in its development towards the margin" is an accident often seen in the cancellated species. Similar specimens of *V. neglecta*, no. 54, collected at Cape St. Lucas by Mr. Xantus, agree with *undatella* in all respects, except that this is violet within, *neglecta* being white. Ligament-area (as in *neglecta*) smooth in one valve only.]

77. *Venus Adamsii*, Rve. Japan. [Closely related to *Tapes laciniata*, San Diego, in size, aspect, hinge, &c. Differs in mantle-bend being not so long or pointed, and the radiating sculpture much finer := *V. rigida*, Gld., MS., in Stimpson's list; non Gld. in 'Otia.']

80. *Venus ornatissima*, Brod. Panama, sandy mud, 10 fms., *Cuming*. Still unique. [Like *V. gnidia*, jun., but radiating ribs coarser and more distant; concentric frills not palmated; lunule pale, laminated.]

87. *Venus callosa* [Sby., non] Conr. Sandwich Is. and Calif. [*Vide* note to no. 59. This is the *V. Nuttallii* of the Brit. Assoc. Report. Those who regard it as distinct from *fluctifraga*, of which *gibbosula*, no. 47, is the extreme form, may retain the name *callosa* of Sby., but not of Conr. Conrad's species = *C. nobilis*, Rve.; differing from the true *Callistæ*, as *Mercenaria* does from *Venus*, in having the ligament-plate rugose.] = *V. fluctifraga*, Sby., teste Rve. *in errata*.

105. *Venus bilineata*, Rve. Gulf Calif. Partakes of the characters of *compta* and *subimbricata*: all three may indeed be different states of one and the same species. [The shell figured at 105*b* has all the peculiar features of *compta*, which are clearly marked within; only the concentric waves are closer than usual. The shell figured at 105*a* appears to be the true *undatella*, only in fine condition, the type being rubbed. It has exactly the same internal characters, including colour; only the colour-lines outside are arranged in rays instead of Vs. Mr. Reeve, however, retains his different opinion.]

116. *Venus Cypria*, Sby., P. Z. S. 1852. Is. Plata, West Columbia. [From same district, teste Schott in Mus. Smiths.] Has all the appearance of being an attenuately produced form of the West Indian *V. paphia* [which is also from Cape Verd Is., teste Macgillivray in Brit. Mus.].

11. *Dione* maculata*, List. West Indies; Brazil; Pacific Ocean. Widely distributed in both hemispheres. [No authority for the Old World; the Pacific shells are *Callista chionæa*, var.]

15. *Dione nobilis*, Rve., 1849. Cal. [= *C. callosa*, Conr., 1837. The original name, from type, had been communicated to Mr. R., but is not quoted.]

20. *Dione semilamellosa* †, Gaud., = *C. lupanaria*, Less. Centr. Am. [= *lupinaria*, Maz. Cat., no. 95. *Vide* Deless. Rec. Coq. pl. 19. f. 2: "China Seas," no authority.]

21. *Dione brevispinata*, Rve., = *brevispina*, Sby. [Gulf of] California. [Scarcely differs from *C. rosea*, jun.]

22. *Dione multispinosa*, Sby. Peru. Concentric ridges thinly laminated; spines slender and numerous. [An extreme form of the Pacific *C. Dione* (teste Hanl.); distinct from *semilamellosa*.]

23. *Dione Veneris*, D'Arg. Conch. pl. 21. f. 1, = *V. Dione*, Ln. West Ind. and

* The figured types of this genus had been accidentally mislaid; and might alter the judgments given in the text.

† "For obvious reasons, I think it best to abandon the foul name given to this lovely species by Lesson," Rve. (*Vide* Maz. Cat. p. 70, note.) ? Would not the same reasons lead to the alteration of *meretrix*, *impudica*, &c.

Centr. Am. [The Pacific shells should rank with species 22, if supposed distinct. The fig. is 24, not 23.]

24. *Dione exspinata*, Rve. Centr. Am. Distinct, if the others are; like *semilamellosa*, without spines. [Appears to be *C. rosea*, jun. The fig. is 23, not 24.]

25. 28, *a, b.* *Dione circinata*, Born. Mazatlan, Mus. Cum. [without authority.] = *V. rubra*, Gmel., + *V. Guineensis*, Gmel., + *C. alternata*, Brod. [f. 28 represents *alternata*; the other figures appear to be from West Indian specimens, though that ancient locality is not mentioned. Several of the reputed West Coast shells are, however, of the typical form and colour.]

33. *Dione unicolor*, Sby., = *Chione badia*, Gray, = *Cyth. ligula*, Anton. W. Columbia.

38. *Dione prora*, Conr. "Cape St. Lucas, Xantus, California; Carpenter." [A very distinct form among the thin inflated species; only yet found at the Sandwich Is., v. no. 45.]

45. "(Mus. Smithsonian Institute of N. America.) This shell, from Cape St. Lucas, Xantus, California, proves to be the *Dione prora* (*Cytherea prora*, Conr.) of our preceding plate." [Mr. Sowerby's figure well represents the unique specimen from Cape St. Lucas, which was taken alive by Mr. Xantus. The quotations in Conch. Ic. would lead to the inference that "Xantus" was regarded as that part of "California" in which Cape St. Lucas is situated. Both the external and internal characters require that a separate name be given to the shell, which stands as *Callista pollicaris*, Annals Nat. Hist. vol. xiii. p. 312.]

46. *Cytherea consanguinea*, C. B. Ad. Mus. Cum. Apparently a small specimen of a variety of *C. læta*. [Panama. Differs from *C. læta* in internal characters.]

62. *Dione pannosa*, Sby., = *Cytherea lutea*, Koch, + *Callista puella*, Cpr. Chili, Peru, Mazatlan. [No authority for Mazatlan. The name *puella* given to the Cape St. Lucas specimens was intended as varietal; although Mr. Cuming regards the Peruvian and Peninsular forms as distinct. It is not known along the Central American coast.]

25. *Circe nummulina*, Lam. "Central America." [Probably not from the American seas. Admiral Sir E. Belcher is, however, confident that he dredged many well-known E. Indian forms in deep water, off San Blas.]

27. *Cytherea*. In this genus are grouped the *Trigonæ*; besides the typical species, = *Meretrix*, Gray.

3. *Cytherea crassatelloides*, Conr. "Bay of California." [Not known geographically. The shell is not found in the Gulf, being a most characteristic Californian species. San Francisco, S. Diego, &c.]

27. *Cytherea radiata*, Sby., + *C. gracilior*, Sby., = *V. Salangensis*, D'Orb. = *T. Byronensis*, Gray. Salango and Xipixapi, 9 fms. sandy mud, *Cuming*.

45. *Cytherea nitidula*, Lam. Mediterranean. [The figures and descriptions of Sby. and Rve. well represent specimens from Cape St. Lucas, *Xantus*. Perhaps not identical with Lam.'s species.]

9. *Tapes grata*, Desh. Philippines. [May stand as *T. Deshayesii*, if it be conceded that Say's *V. grata* ranks best with *Tapes*.]

7. *Solarium granulatum*, Lam. Mexico.

8. *Solarium verrucosum*, Phil. W. Indies. ? = *S. granulatum*, var.

13. *Solarium placentula*, [Rve. = *placentale*,] Hds. Bay Magdalena, 7 fms., *Belcher*.

19. *Solarium quadriceps*, Hds. Panama. Young state of same type as sp. 7 and 8, "from same locality (Pan., Mex., W. I.)," but grows much larger. [The Texan shells in Mus. Smiths. are as large as those from Cape St. Lucas: the variations on each coast are coordinate.]

63. *Kiener*.—The following species may be added to the list quoted from "Coquilles Vivantes," in Rep. pp. 293, 294:—

Page.	Pl.	Fig.	
15.	3. 11.	2. 4.	*Conus regius*, Chem., = *C. princeps*, Ln., W. Mexico.
212.	98. 100.	3. 1,1*.	*Conus Largillierti*, Kien. Mexico. [Coast not stated.]

Page.	Pl.	Fig.	
213.	98.	2.	*Conus Philippii*, Kien. Mexico. [Coast not stated.]
65.	27.	3.	*Pleurotoma triticea*, Kien. Indian Ocean. [Probably *Cithara stromboides*, Val.; Cape St. Lucas.]
45.	9.	2.	*Columbella suturalis*, Gray (Griff. pl. 41. f. 2) = *C. costata*, Ducl. Mon. pl. 12. f. 1, 2. Pacific, Coasts of Peru [= *Anachis fluctuata*, Sby.].
46.	16.	4.	*Columbella bicolor*, Kien. *Hab.* ?— [= *A. rugosa.*]

64, 65. (*German Authors.*) *Pfeiffer.*—Everything relating to the land-shells of North America will be found so thoroughly collated in the works of Mr. Binney (v. *infrà*), that it is only judged needful to present here the most important references to the writings of the great authority on the *Pulmonata*. The student must necessarily consult the 'Symbolæ ad Historiam Heliceorum, Cassel, 1841' *et seq.*, which contains the following original authorities:—

1846. p. 89. *Achatina Californica*, Pfr. Monterey, Cal.
91. *Achatina (Glandina) turris*, Pfr. *Hab.* ?— [Genus altered to *Oleacina*, Mon. Hel. iv. p. 640. Maz. Cat. 231.]

In the same author's great work, 'Monographia Heliceorum Viventium,' Lipsiæ, 1847–8, occur—

		Page.	
Vol. I.	1847.	324.	*Helix Sagraiana*, D'Orb. Cuba, California. [Sowerby's error, copied by succeeding writers. The species is exclusively Cuban.]
		338.	*Helix fidelis*, Gray. Oregon. = *H. Nuttalliana*, Lea.
		339.	*Helix Californiensis*, Lea. California. + *H. Nickliniana*, Lea. [Quoted as a distinct species in Vol. IV. p. 269.]
	(Vol. 3.	229.	= *H. arboretorum*, Val.)
		341.	*Helix Townsendiana*, Lea. California.
	(Vol. 3.	229.	= *H. pedestris*, Gld., + *ruida*, Gld.)
		428.	*Helix Oregonensis*, Lea. Oregon.
	(Vol. 4.	227.	= *H. Dupetithouarsii*, teste Pfr.)
Vol. II.	1848.	101.	*Bulimus Mexicanus*, Lam. Tabasco, Mexico. = *H. (Cochlogena) vittata*, Fér.
	(Vol. 4.	402.	= *Orthalicus M.*, Cpr.)
		143.	*Bulimus zebra*, Müll.* Mexico, &c. = *Zebra Mülleri*, Chem. = *Bulimus undatus*, Brug.* = *Orthalicus livens*, Beck*, + *B. princeps*, Brod. + *B. melanocheilus*, Val.
		231.	*Bulimus (Cochlogena) melania*, Fér. California. = *Melania striata*, Perry = *B. bovinus*, Brug.
Vol. III.	1853.	127.	*Helix Pandoræ*, Fbs. St. Juan del Fuaco.
	(Vol. 4.	347.	= *H. Damascenus*, Gld.)
		415.	*Bulimus Humboldti*, Rve. = *B. Mexicanus*, Val. [? non Lam.] Mexico.
		422.	*Bulimus Californicus*, Rve. California.
Vol. IV.	1859.	89.	*Helix Mazatlanica*, Pfr., n. s. (Mal. Blätt., Apr. 1856, p. 43.) Mazatlan.
		268.	*Helix exarata*, Pfr., n. s. California.
		270.	*Helix reticulata*, Pfr. (Mal. Blätt. May 1857, p. 87). Cal.
		276.	*Helix Mormonum*, Pfr. Mormon Island, California.
		347.	*Helix cultellata*, Thomson. Contra Costa Co., California.
		350.	*Helix arrosa*, Gld. *Hab.* ?— [California.] + *æruginosa*, Gld.
		420.	*Bulimus chordatus*, Pfr. (Mal. Blätt., April 1856, p. 46.) Mazatlan.
		472.	*Bulimus Ziegleri*, Pfr. (Mal. Blätt., Dec. 1856, p. 232.) Mexico. = *Orthalicus Z.*, Cpr.

* These appear as three distinct species in Vol. IV. p. 588–9, with the addition of *B. longus*, Pfr. (= *Orthalicus l.*, Mal. Blätt., Oct. 1856, p. 187.)

In the 'Monographia Pneumonopomorum Viventium, &c., Cassellis, 1852,' by the same learned author, the following is the only species which occurs:—

Suppl. 1858, Vol. II. p. 7. *Truncatella Californica,* Pfr. San Diego.

In Wiegmann's 'Archives für Nat.,' 1837, vol. i. p. 285, occurs the following species, also without authority:—

Perna quadrata, Anton. California.

In Troschel's 'Archives für Natur' are quoted the following:—

1843. Vol. II. p. 140. *Fasciolaria sulcata,* Less. Acapulco.
1849. „ p. 99. *Terebratula Californica,* Linsley.

In the 'Abbildungen und Beschreibungen neuer oder wenig gekannter Conchylien, herausgegeben von Dr. R. A. Philippi,' Cassel, 1845–51, are figured the following, which must be quoted as being original descriptions, or for the synonymy:—

	Page.	Pl.	Fig.	
Feb. 1846.	4.	1.	9.	*Cyrena solida,* Phil. California, &c.
Aug. 1846.	24.	4.	7.	*Tellina pisiformis,* Ln. Mazatlan, &c. = *L. pulchella,* Ad. ? = *Cardium discors,* Mont.
Oct. 1844.	4.	..	..	*Cytherea Dunkeri,* Phil. W. C. Mexico. = *C. Pacifica,* Mus. Berol., non Dillw.
Apr. 1847.	33.	7.	1.	*Cytherea (Artemis) gigantea,* Sby. California. ? = *Artemis ponderosa,* Gray.
Jan. 1845.	1.	1.	1.	*Murex nigritus,* Phil. ? W. C. Mexico.
April 1847.	11.	7,8.	1.	*Haliotis fulgens,* Phil. ? California. = *H. splendens,* Rve.
Oct. 1846.	5.	2.	1,10.	*Turbo Fokkesii,* Jonas. Gulf of California.
	8.	2.	9.	*Trochus strigilatus,* Ant. California. = *T. pellis-serpentis,* Wood.
July 1844.	7.	2.	5.	*Patella (Acmæa) discors,* Phil. Mexico.
April 1850.	9.	2.	8.	*Lucina obliqua,* Phil. ? W. C. America.
	9.	2.	9.	*Lucina pisum,* Phil. Mazatlan.
	2.	1.	3.	*Pecten tunica,* Phil. "Sandwich Islands*. *R. B. Philippi.*" Jan. 1844. [= *P. latiauritus,* Conr., teste Hanl. S. Diego, &c.]
	5.	1.	5.	*Pecten Fabricii,* Phil. Greenland. [= *P. Islandicus,* jun. Non *P. Fabricii,* Gld., = *P. Hindsii,* jun.]
	11.	6.	9.	*Litorina aberrans,* Phil., P. Z. S. 1845, p. 142. Panama, on rocks. [= Tall var. of *L. conspersa.*]

In Dr. L. Pfeiffer's 'Novitates Conchologicæ,' Series II., Marine Shells, by Dr. W. Dunker, Cassel, 1858, occur the following species from Sitka:—

Page.	Pl.	Fig.			
1.	1.	3, 4.	*Tritonium carinatum,* Dkr. [= *T. angulosum,* Mörch, on plate.]	Sitka.	[Should be pl. 2. f. 3, 4.]
2.	1.	1, 2.	*Tritonium Mörchianum,* Dkr.	Sitka.	[Should be pl. 2. f. 1, 2.]
3.	2.	5, 6.	*Tritonium rutilum,* Mörch.	„	[Should be pl. 1. f. 5, 6.]
4.	1.	5, 6.	*Tritonium Rombergi,* Dkr.	„	[Should be pl. 2. f. 5, 6.]
2.	2.	3, 4.	*Neptunea harpa,* Mörch.	„	[Should be pl. 1. f. 3, 4.]
7.	2.	1, 2.	*Neptunea castanea,* Mörch. [= *N. badia,* on plate.]	„	[Should be pl. 1. f. 1, 2.]
35.	10.	6, 7.	*Murex (Hemifusus) Belcheri,* Hds., var. ?— [= *Chorus B.,* L. Cal.]		
39.	12.	7–9.	*Cytherea (Tivela) arguta,* Röm. Isthmus of Panama. Resembles *C. (Trigona) mactroides,* Born. [Probably Caribbean.]		

66. *British Museum Collection.*—"*Lunatia ravida,* Souleyet, Panama,"

* A large number of Californian shells have been assigned to the Sandwich Is., in consequence of the abundant trade between the two localities. They may often have been obtained at Honolulu by naturalists, who had no reason to doubt their having lived there. All that is known of the genuine Hawaian fauna will shortly be published by Mr. Sowerby, for W. H. Pease, Esq., of Honolulu.

is given without authority; and the locality is probably erroneous. Various other shells are scattered in the national collection, assigned either generally to the West Coast or to special localities, which it has not been considered needful to tabulate without confirmation.

68. *Various sources.*—Under this head may be arranged gleanings from European authors not consulted in preparing the first Report.

In the 'Histoire Naturelle des Coquilles,' by L. A. G. Bosc, Paris, 1830, the following species, not previously quoted, are assigned to the West Coast, but without authority:—

Vol.	Page.		
III.	44.	*Venus paphia.*	W. America.
	280.	*Nerita fulgurans,* Bosc.	W. C. America.
	290.	*Natica rugosa,* Chem.	"
IV.	60.	*Helix peregrina.* Island on	"
	152.	*Trochus solaris.*	" &c.
	156.	*Trochus radiatus.*	" &c.
	219.	*Murex lima.*	W. C. N. America.

In Lesson's 'Illustrations de Zoologie,' Paris, 1831–2, appear—

Plate.	
2.	*Calypæopsis tubifera,* Less. [=*Crucibulum spinosum*].
41. (1832.)	*Trichotropus Sowerbiensis,* Lesson. Seas of New World. =*Trichotropis bicarinata,* Br. & Sby.=*Turbo bicarinatus,* Sby.
48.	*Terebra flammea,* Less. [?=*T. strigosa*], Antilles; Isth. Panama.
51.	*Tegula elegans,* Less. [=*T. pellis-serpentis*]. Isth. Panama.

The following West Coast shells are named and figured by Dr. Gray in 'Griffith's Edition of Cuvier's Animal Kingdom,' London, 1834. In some instances there are also a few words of description:—

Plate.	Fig.	
1.	3.	*Litorina pulchra.*
41.	5.	*Turbenella ceratus* [? *Turbinellus*].
41.	6.	*Columbella suturalis* [Kiener figures this shell for *Anachis fluctuata,* Sby., 1832. The original might stand for many species].
36.	2.	*Nassa Northiæ* [=*Northia serrata,* Kien.].
36.	3.	*Turbinella tubercularis* [=*Latirus tuberculatus* (=*ceratus,* C. B. Ad.)].
23.	5.	*Terebra Africana.* [The Gulf Cal. shell,=*variegata.*]
25.	2.	*Triton (Pusio) elegans* [=*Pisania insignis,* Rve., 1846].
37.	2.	*Columbella harpaformis* [=*harpiformis,* Sby.].
37.	6.	*Clavatula Griffithii.* [Probably=*Pl. funiculata.* The shells in this plate are reversed, but are repeated correctly in pl. 37*.]
19.	1.	*Cytherea Dronea,* var. [=*C. semilamellosa,* Gaud.; perhaps intended for *C. dione,* var.].

In Woodward's most valuable 'Manual of the Mollusca,' London, 1851–6, the following species are quoted as from "California":—

Page.	Pl.	Fig.	
108.	5.	5.	*Cancellaria reticulata,* Dillw. [?W. Indies.]
171.			*Physa Maugeræ.* [?Ecuador.]
329.	23.	22.	*Parapholas bisulcata,* Conr. [*v.* Rep. p. 265. Not known from the Californian or W. Mexican coasts. Resembles *P. calva*].

In the very valuable handbook of bivalves, 'Recent Shells, by S. Hanley, London, 1842–56,' will be found either quoted or original diagnoses of all West Coast species known to the learned, patient, and minutely exact compiler. As the locality-marks are simply transcripts, they are not here repeated, especially as "California" is used for both the temperate and the tropical faunas. The following synonyms will be serviceable to the student:—

Page.	
16.	*Solen subteres,* Conr., ?=*S. Dombei,* ?+*Californianus.* Upper Cal.
28.	*Lutraria lineata,* Say,=(*Cryptodon*) *Nuttallii* [teste Hanl., non] Conr.

Page.
72. *Tellina inconspicua*, Br. and Sby., ? = *Sanguinolaria* [*Californiana*, Conr., non] *fusca*, Conr. [=the Eastern species].

In the Appendix are the following species, of which small figures are given, to correspond with those in Wood's Ind. Test:—

Page.	Pl.	Fig.	
339.	13.	50.	*Periploma obtusa*, Hanl. W. America.
341.	12.	5.	*Amphidesma proximum*, C. B. Ad., = *A. corrugatum*, Ad. Mexico.
373.	18.	51.	*Arca Reeveana*, D'Orb. W. America. = *A. squamosa*, var., D'Orb. = *A. Helbingii*, Rve.
388.	24.	40.	*Meleagrina Mazatlanica*, Hanl. Mazatlan [= *M. fimbriata*, Dkr.].

The following are extracted from the 'Journal de Conchyliologie,' Paris, 1850:—

		Page.	Pl.	Fig.	
No. 1.	Feb. 1850.	57.	3.	4.	*Columbella Haneti*, Petit. ? Mazatlan.
4.	Dec. 1850.	410.			Observations on *Nerita scabricosta*, Lam., by Petit. West Coast of N. America.
Vol. 3.	1852.	57.	2.	11.	*Mitra Haneti*, Petit. Mazatlan.
4.	1853.	53.	2.	11,12.	*Natica Taslei*, Recl. Mazatlan.
4.	1853.	84,166.	6.	13–15.	*Gnathodon trigonum*, Petit. Mazatlan [= *M. mendica*, Gld., 1851].
4.	1853.	119.	5.	12.	*Recluzia Rollandiana*, Recl. [Genus described.] Mazatlan.
4.	1853.	154.	5.	9,10.	*Natica Moquiniana*, Recl. ? West Coast of America.
Series II. Vol. 2.	Oct. 1857.	171.			*Adeorbis Verrauxii*, Fischer. } California.
		285.	6.		*Skenea Verrauxii*, Fischer. } California.
		292.			Review of the Brit. Assoc. Report and Brit. Mus. Reigen Catalogue, by Fischer.
Vol. 9.		209.			Review of the Smithsonian Check Lists, by Fischer.

The following species are figured in Chénu's 'Illustrations Conchyliologiques'; but no authority is given for the localities, nor etymology for the remarkable names:—

Page.	Pl.	Fig.	
8.	2.	19, 20.	*Oliva selasia*, Ducl. Acapulco.
13.	7.	3, 4, 21, 22.	*Oliva caldania*, Ducl. California.
13.	7.	5, 9, 23, 24.	*Oliva razamola*, Ducl. California.
17.	14. 15.	7. 1, 2, 10, 11.	*Olivia azemula*, Ducl. California.
19.	16.	7, 8.	*Oliva mantichora*, Ducl. California.
19.	12. 17.	10, 11. 7, 8.	*Oliva pindarina*, Ducl. California.
28.	27.	9, 10.	*Oliva todosina*, Ducl. California.

An excellent commentary on the above species, and on the difficult genus to which they belong, is supplied in the 'Revue Critique du genre Oliva,' by M. Ducros de St. Germain, Clermont, 1857. It was written, not from the well-known London collections, but from a very large series containing all the types figured by Duclos. The following is the author's arrangement of the West Coast forms, excluding citations of well-known species.

No. Page.
25. 49. *Oliva angulata* does not include *azemula*, Ducl., as Rve. says; that being a var. of *ponderosa* + *erythrostoma*.
26. 50. *Oliva Maria*, n.s., pl. 2. f. 26, *a*, *b*; intermediate between *Julietta* and *angulata*. California, teste Duclos. [Appears to be one of the vars. of *Cumingii*.]
28. 52. *Oliva reticularis*. To the typical W. Indian shells are united those from California, Panama, Madagascar, Japan, N. Holland, N. Zealand, &c.

No. Page.

The synonymy includes *venulata*+*araneosa*+*Cumingii*+*oriola* (Ducl. non Lam.) + *pindarina* + *fusiformis* + *timoria* + *obesina* + *tisiphona* + *memnonia*+*aldinia*+*oniska*+*caldania*+*harpularia*+*candida*+*ustulata*.

63. 83. *Oliva Steeriæ*, Rve. Mazatlan, *Ed. Verreaux*. = [*testacea*, var.]

67. 86. *Oliva Deshayesiana*, n. s. Atlas, pl. 3. f. 67, *a*, *b*: intermediate between *Braziliensis* and *auricularia*. California, teste Duclos. [Certainly not from the West Coast.]

68. 87. *Oliva volutella*, Lam.+*razamola*, Ducl.

71. 89. *Oliva undatella*, Lam.+*nedulina*, Ducl.; but not *ozodona*, Ducl., as Rve. says.

73. 89. *Oliva lineolata*, Gray in Wood's Ind. Test. = *purpurata*, Swains. = *dama*, Ducl. [i. e. *dama*, Goodall in Wood, = *lineolata*, Gray MS. in B. M., Zool. Beech. Voy.]

75. 91. *Oliva selasia*, Ducl. Acapulco; teste Ducl. "We know nothing of this remarkable shell but the specimen figured by the author."

85. 96. *Oliva mutica*, Say+*rufifasciata*, Rve. [assigned by error to the Californian *O. bætica*, var.]+*fimbriata*, Rve.

In the most recent and among the most valuable of the contributions to our knowledge of local faunas, 'Mollusques de l'île de la Réunion, par M. G. P. Deshayes,' Paris, 1863, occur very unexpectedly the following species connected with the West Coast, either by name or by identity. The list of 560 species from this little island, which the researches of M. Maillard has brought to light, contains several West Indian forms and a large number known in the Central Pacific and even the Sandwich Islands.

No. Page.

38. 16. *Chama imbricata*, Brod.

47. 19. *Lucina tigerina*, Ln. "Common on sands, with *Capsa deflorata*, as at the Antilles."

65. 23. *Modiola cinnamomea*, Chem. [*Botula*, Mörch, teste A. Ad.]

110. 40. *Chiton sanguineus*, Desh. pl. 6. f. 4–7. [Non *Ch. sanguineus*, Rve. As the West Coast shell = *Ischnochiton limaciformis*, Sby., the Bourbon species may retain its name, especially if, as is probable, it belongs to another genus.]

197. 68. *Solarium* [*Torinia*] *variegatum*, Lam.

216. 74. *Turbo phasianellus*, Desh. Minute edition of *T. petholatus*; nacreous. [Not congeneric with *T. phasianella* (Phil.), C. B. Ad., Panama shells, no. 282.]

233. 79. *Natica Marocchiensis*, Lam., Q. and G. Astr. pl. 66. f. 16–19. [? = *maroccana*, Chem.]

307. 95. *Cerithium uncinatum*, Gmel. Thes. Conch. pl. 180. f. 78, 79. [? = *C. uncinatum* (Gmel.), Sby.]

393. 114. *Purpura patula*, Lam. [Linn.].

403. 115. *Purpura ?ochrostoma* (Bl.), Rve. [*Sistrum*].

405. 115. *Purpura* (*Coralliophila*) *madreporarum*, Sby. [? *Rhizocheilus*. = *Leptoconchus monodonta*, Quoy, teste Gld. Otia, p. 215.]

446. 132. *Terebra luctuosa*, Hds.

560. 140. *Cerithium Gallapaginis* (A. Ad.), Sby. Thes. [Sby.'s species = *interruptum*, Mke., non C. B. Ad., no. 198, rough var.] *

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93. *Smithsonian Institution.*—At the time of the first Report, the temperate fauna of the West Coast was only known through sources liable to error, the collectors having visited other regions besides Oregon and California, and the species described by American authors being but imperfectly understood in this country. The large accession to the number of authentic species, the important elimination of synonyms, and the assignment of ascertained loca-

* The review of the remainder of the first Report, nos. 69–92, will be postponed till after the production of the new materials, which are almost entirely from American sources.

lities, which are placed on record in this Report, are due almost entirely to the stimulus afforded to science in general, and to this branch especially, by the Smithsonian Institution at Washington, D. C. The fund bequeathed by Mr. Smithson, "for the increase and diffusion of knowledge among men," having been declined by the Universities to which it was offered in the Old World, is held (in trust only) by the U. S. Government *. It is administered by a permanent body of Regents, according to a constitution drawn-out at their instance by the Secretary, Prof. J. Henry, LL.D. It may be safely stated that to his unswerving consistency, cautious judgment, and catholic impartiality it is mainly owing that, during various political and social changes, the Institution has not only steered clear of all party bias in the United States, but has distributed its advantages with equal hand on both sides of the Atlantic. The Natural History department is under the special superintendence of the Assistant-Secretary, Prof. Spencer Baird, M.D., whose indefatigable zeal, fertility of resource, and thorough knowledge of the requirements of the science have enabled the Institution, by a comparatively small outlay, not only to amass in a few years an enormous store of accurate materials, but also to eliminate from them a series of publications on various important branches of American zoology. The contributions of the Smithsonian Institution to our knowledge of the West Coast fauna may be considered under [A] its collections and [B] its publications.

[A] *Smithsonian Collections.*—According to the present law, all collections made in expeditions fitted out by the Government become the property of the Smiths. Inst., with liberty to exchange duplicates. Its museum, therefore, is rich in types; and its liberal policy allows of all duplicates being transmitted to public collections, to schools of science, or to individuals engaged in special departments of study. Not being forced into an unalterable plan of operations, like many leading museums of the Old World, permission was given to send nearly the whole of the molluscs to this country, that they might be compared with the Cumingian, the Brit. Mus., and other leading collections †. The importance of thus establishing a harmony of nomenclature for species on both sides of the Atlantic can scarcely be over-estimated. The previous want of it can be abundantly seen by comparing paragraphs 39, 43, 54, &c., in the first and in this Report. The West Coast collections belonging to the Smiths. Inst. are mainly from the following sources:

a. The United States Exploring Expedition, under Capt. (afterwards Admiral) Wilkes, 1837–1840, v. par. 43.

b. The North Pacific Exploring Expedition, under Capt. Rogers, 1853–1855. Collector, Dr. Stimpson.

c. The Pacific Railroad Expedition, 49th parallel, under Governor J. J. Stevens, 1853–54. Collections made in Puget Sound by Dr. Suckley, and at Columbia River by Dr. J. G. Cooper. Dr. Suckley also collected at Panama.

* The war has but to a limited extent curtailed the funds and interfered with the operations of the Institution.

† The Cunard Steamship Company have most liberally conveyed these stores across the Atlantic, free of cost. The British and American Governments have allowed special facilities for passing the Custom Houses without derangement. Similar acts of liberality and courtesy are continually afforded to the Smiths. Inst.—The materials for this Report have been placed unreservedly in the hands of the writer, although he went to Washington as a complete stranger, and with no other introduction than his published writings. He was, however, at that time (Dec. 1859) directed to maintain silence on the slavery question, and not even to associate with coloured persons—a strange embargo to lay on the private life of a working naturalist! Now, however, there is the same freedom of speech on that subject as in England.

d. The Pacific Railroad Survey, under Lieutenant R. S. Williamson, 1853. Collector, Dr. A. L. Heermann.
e. The Pacific Railroad Survey, under Lieutenant R. S. Williamson, 1855. Collector, Dr. J. S. Newberry.
f. United States and Mexican Boundary Survey, under Major W. H. Emory, 1852. Collector, Arthur Schott.
g. Colorado Expedition, under Lieutenant J. C. Ives. Collector, Dr. J. S. Newberry.
h. The United States North-West Boundary Survey, under Com. A. Campbell. Collectors, Dr. Kennerley and Mr. George Gibbs.

Besides the above official explorations on the American side, during a period in which the British Government only fitted out a single expedition coordinate with *h*, the Smiths. Inst. has received a large number of private collections from their correspondents, of which the following are the principal:—

i. Mr. Jas. G. Swan, from Port Townsend, Cape Flattery, Neeah Bay, and the neighbouring shores of Vancouver; at intervals, during many years.
j. Dr. J. G. Cooper, early private collections from Shoalwater Bay and various stations in California and from Panama; and lately the dredged collections of the California State Geological Survey, of which a portion were sent in advance by Dr. Palmer.
k. California Academy of Natural Sciences, duplicates of their collection, with the privilege of inspecting unique specimens.
l. Dr. E. Vollum, U.S.A., from Fort Umpqua.
m. Lieutenant W. P. Trowbridge, from coast of Oregon and California.
n. Dr. J. A. Veatch, from the peninsula of Lower California, and especially from Cerros Island.
o. Mr. A. S. Taylor, from Monterey.
p. Mr. Andrew Cassidy, from S. Diego.
q. Rev. J. Rowell, now of San Francisco, from various stations in both faunas, and especially from Sta. Crux, and the Farallones Is.
r. Mr. John Xantus, of the U. S. Coast Survey, from Cape St. Lucas. Specimens were received through him from Socorro Island (one of the Revillagigedo group), Tres Marias and Margarita Island.
s. Captain C. P. Stone, from Guaymas and the northern part of the Gulf of California.
t. Captain C. M. Dow, from the coast of Central America.
u. Dr. J. H. Sternberg, from Panama.
v. Dr. J. H. Frick, Mr. James Hepburn, and others, from San Francisco.
w. Mr. C. N. Riotte, U. S. Minister to Costa Rica, from Puntas Arenas.
x. Mr. W. H. Pease, of Honolulu, collections made by his agents at various stations on the coast, particularly at Margarita Bay.

Collections have also been received from various expeditions already tabulated in the first Report; and from stray quarters not here included because their accuracy may admit of doubt. The species received from the most important of these sources will be enumerated in their order; of the remainder, exact lists may be consulted by the student in the Smithsonian Catalogues, and the combined results will be found tabulated as 'Pacific Railroad Expeditions' or 'Smithsonian Collections.'

[B] *Smithsonian Publications.*—These may be classed under three heads. (1.) Works published by the U. S. Government, with more or less of assistance derived from and through the Smiths. Inst. (2.) The 'Smithsonian Contributions to Knowledge,' printed in 4to, and answering to the 'Trans-

actions' of English learned societies; and (3.) The 'Miscellaneous Collections,' in 8vo, answering to the 'Proceedings' of the societies:—

(1.) The series of ten 4to volumes, called 'Pacific Railroad Reports,' contains a complete *résumé* of the natural history of the western slope of North America. The Recent and Tertiary Fossil Mollusca will be analyzed in the following pages. Accounts have also been published of the natural history of other expeditions.—The annual volumes of 'Reports of the Regents of the Smithsonian Institution,' published by the U. S. Government, contain exact accounts of the assistance rendered to the expeditions by the Smiths. Inst., as well as lectures and articles on special subjects. In these will be found full particulars of the principles which regulate the natural-history workings of the Institution*.

(2.) The only paper bearing on our present inquiry as yet published in the 'Contributions' is on the "Invertebrata of the Grand Manan," by Dr. W. Stimpson, which should be consulted by all who desire to institute a comparison between the sub-boreal faunas on the two sides of the Atlantic.

(3.) The 'Miscellaneous Collections' are all stereotyped, and very freely circulated. Among them will be found "Directions" for collecting specimens of natural history, with special instructions concerning the desiderata on the Pacific coasts. These have been widely distributed among the various government officials, the *employés* of the U. S. Coast Survey, and the variously ramified circulating media at the command of the Smiths. Inst.; and have already borne a fair share of important results, although the war has greatly impeded the expected prosecution of natural-history labours. "Check Lists" have been published "of the Shells of North America, by I. Lea, P. P. Carpenter, W. Stimpson, W. G. Binney, and T. Prime," June 1860. No. 1 contains the Marine Shells of the "Oregonian and Californian Province," and No. 2 of the "Mexican and Panamic Province." They are chiefly compiled from the first British Association Report, with such elimination of synonyms and doubtful species, and addition of fresh materials, as had become available up to the date of publication. They were not intended to be quoted as authorities; and so rapid has been the accumulation of fresh information that no. 1 is already out of date. In the "Terrestrial Gasteropoda," by W. G. Binney, list no. 1 contains the "species of the Pacific coast, from the extreme north to Mazatlan," to which many additions have since been made. In the list of "Fluviatile Gasteropoda," also by W. G. Binney, "the letter **W** distinguishes those confined to the Pacific coast, **WE** is affixed to those found in both sections of the continent, and **M** designates the Mexican species. From the starting-point of this list considerable progress has already been made. In the brief list of "Cyclades, by Temple Prime," the Mexican and Central American species are similarly designated; but the western species and those common to the Pacific and Atlantic United States are not distinguished. In the list of "Unionidæ," by Dr. I. Lea, whose life-long devotion to the elucidation of that family is everywhere gratefully acknowledged, the Pacific species are designated by a **P**. The large series

* The 'Lectures on Mollusca,' in the Vol. for 1860, pp. 151–283, will perhaps be found useful as a digest of classical forms. It was to have been illustrated with copies of woodcuts, kindly promised by Dr. Gray, and since placed at the disposal of the Smiths. Inst. by the courtesy of the Trustees of the British Museum; but, unfortunately, the blocks were not to be found at the time. They will appear, however, in forthcoming Smithsonian publications. The 'Lecture on the Shells of the Gulf of California,' in the Vol. for 1859, pp. 195–219, contains in a popular form much of the information distributed through the Brit. Mus. Maz. Cat.

of specimens, representing varieties and ages, in Dr. Lea's private collection are well deserving of close study. Their owner shares the liberality of Mr. Cuming in making them available for all purposes of scientific inquiry.

The Smiths. Inst. has just issued from the press the first part of the 'Bibliography of North American Conchology, previous to the year 1860,' by W. G. Binney, containing references to all printed information on North American shells by native writers. It is divided into "§ A. American descriptions of North American molluscs; § B. American descriptions of foreign molluscs; § C. Descriptions of foreign species by American authors in foreign works." The work is prepared with unusual care and completeness, and with the accurate judgment which characterizes all Mr. Binney's writings. It contains, under every separate work or paper, "a list of species therein described or in any important manner referred-to, together with their synonymy, locality, and the volume, page, plate, and figure relating to them." The second part, containing similar references to American species described by European writers, is now passing through the press. Mr. Binney has most kindly sent the proofs to the writer (as far as p. 287), which have been freely used in preparing this Report, and have supplied various important sources of information. It undertakes to provide for the whole North American continent what has been here attempted for the West Coast; and in much greater detail, as not only the first description, but all subsequent quotations are duly catalogued. It may be regarded as a complete index of references to all works on North American malacology. The student, in making use of it, will remember that it is only with the Pulmonates that Mr. Binney professes an intimate acquaintance. For these the work may be regarded as complete. But, in other departments of the science, only those shells which are *assigned by the authors* to North America are quoted; consequently a large number of species are passed-over which are truly American, but are assigned to other places, or described without locality. Also, species really belonging to other faunas, but falsely attributed to North America, duly appear as though genuine; and the additional localities frequently assigned by the authors (which are often the real habitats) are seldom quoted. Moreover the citations stop at Mazatlan; consequently, the tropical fauna of the West Coast is but imperfectly represented. Lastly, the authors are not presented in chronological or indeed in any other ostensible order; but it is promised that the necessary information will be given in the index on the completion of the work. The student will further bear in mind that for many reasons no second-hand reference can serve the same purpose as a consultation of the original book. With these cautions the work will be found invaluable by all who are engaged in working-out American species; and great thanks are due to Mr. Binney for undertaking the extreme labour of its compilation, and to the Smiths. Inst. for supplying the expense of its publication. Probably no such work has yet been printed on the malacology of any other country.

Lastly, there is now in preparation a complete series of hand-books on North American malacology, copiously illustrated with wood engravings, and containing a digest of all that is known in each department. The marine shells of the Atlantic are being described by Dr. Stimpson, who is now also engaged in the dissection of the Freshwater Rostrifers; the marine shells of the Pacific are placed in the hands of the writer; the Pulmonates will be thoroughly worked-out by Mr. Binney, the Melaniadæ by Mr. Tryon, and the Cycladidæ by Mr. Prime. Thus it appears that while other Americans have been eagerly devoting themselves to destroying each other's lives, and in some instances invoking the name of science to assist in the degradation

of the coloured portion of our race *, the malacologists have been unusually zealous in advancing their before somewhat slumbering study; and that while the U. S. Government has suspended the publication of the Reports in progress, preferring to spend the money on war, the Smiths. Inst. has displayed unexpected liberality in preparing and issuing from the press works of a far more comprehensive character, for the peaceful "increase and diffusion of" what will hereafter be regarded as an important branch of "knowledge among men."

94. *North Pacific Exploring Expedition.*—In the year 1853, Dr. W. Stimpson, well known in very early life for his dredging-researches and observations on the marine animals of the Atlantic coast, accompanied Captain Ringold as naturalist to the U. S. "North Pacific Exploring Expedition." Its principal object was to obtain more correct information with regard to the Japan seas and the extreme north of the Pacific, and it was only incidentally that it visited the Californian province. However, Dr. Stimpson's extensive dredgings in the fiords of Japan developed the interesting fact, that while the southern shores presented a fauna essentially Indo-Pacific in its character, and abounding in the usual Cones, Cowries, Olives, &c., the northern slopes of the same islands presented an assemblage of forms far more analogous to the fauna of the Sitka and Vancouver region, and containing many species common to the American coast. During the course of the voyage dredging-collections † were made by Dr. Stimpson at Madeira, Cape of Good Hope, Sydney Harbour, Coral Seas, Port Jackson, Hong Kong (also by Mr. Wright; New Ireland, Lieut. Van Wycke; Gasper Straits, Squires; vicinity of Canton, presented by Mr. Bowring; interior of Hong Kong, Wright); China Sea; Whampoa; Bonin Island; Loo Choo Island; Ousima; Katonasima Straits; Kikaia; Kikaisima; Kagosima [alas!]; Hakodadi; Taniogesima (also Wright, Kent, Kern, Boggs, Carter); Simoda; Niphon (also Brook); Arvatska Bay, Kamtschatka; Aminecheche Island, Avikamcheche Island, Behring Straits; Seniavine Straits, Arctic Ocean (also Captain Rogers); San Francisco; (Puget Sound and Shoalwater Bay, Dr. Cooper, Cat. no. 1849–1856); Tahiti (also Captain Stephens, Kern), Hawaii (also Garrett; Sea of Ochotsk, Captain Stevens). All these were duly catalogued, with stations, depths, and other particulars, and living animals preserved in spirits after being drawn. The expedition appears to have returned in 1856. Although Dr. Stimpson devoted his chief attention to articulate animals, and molluscs occupied but a subordinate share of his attention, it is safe to say that in this short period he collected more trustworthy species of shells, with localities, than were received at the Smiths. Inst. from the united labours of the naturalists of Captain Wilkes's celebrated expedition. Through some unaccountable cause, certain of the most valuable boxes were "lost" between New York and Washington; the remainder were placed in the hands of Dr. Gould for description, with the MS. catalogue, a copy of which forms the "Mollusca, Vol. I.," nos. 1–2003, of the Smiths. Mus. Fortunately, Dr. Gould embraced the opportunity to bring the uncertain shells to London, and compare them with the Cumingian Collection ‡.

* See Prof. Huxley's remarks on the publications of the Anthropological Society, in his Lectures on Mammalia at the Royal College of Surgeons.

† A fuller account of this expedition is here given than is justified from its contributions to the W. American fauna, because no other information respecting it is as yet available to the malacological student.

‡ When he sought similar permission to identify the shells of Captain Wilkes's Expedition, the answer of the celebrated Judge who then had the custody of the collection was (with an oath), "We are a nation of twenty millions, and can do without Europe." Very rapidly has science taught her a better lesson since those days.

Thus a large body of species, *named from types,* was prepared for the New World; but, unfortunately, through imperfect packing and the practice of marking by numbers only, much of the value of this identification was lost. The new species were described by Dr. Gould in the 'Boston Proc. Soc. Nat. Hist.,' 1859–1861; and on completion of the series, the author collected the papers embodying the new species of the two great scientific expeditions, as well as his other scattered publications, and issued them in a most valuable book, entitled 'Otia Conchologica: Descriptions of Shells and Molluscs, from 1839-1862,' Boston, 1862; with "Rectifications," embodying such changes of nomenclature and synonyms as he desired to represent his matured views. In quoting Dr. Gould's writings, therefore, this table should always be consulted. A considerable portion of the specimens have been returned to the Smiths. Inst., of which the larger species are mounted in the collection, and the smaller ones have been sent to the writer to compare with those collected by Mr. A. Adams, which were unfortunately being described in the London journals almost simultaneously. The war has unhappily postponed the intention of publishing the complete lists of species collected and identified with so much accurate care. The following, however, have already been determined by Dr. Gould from the region in which American species occur. The list is given entire (so far as identified), because species as yet known only on one coast of the North Pacific may hereafter be found on the other. It contains (as in the comparison of the Caribbean and West Mexican fauna) (*a*) species certainly identical, (*b*) probably identical, (*c*) "interesting anagues," and (*d*) representative forms.

S.I.Cat. no.

1263. *Crepidula hystryx*, var. Kagosima Bay, Japan. Dead on shore. [=*aculeata*, Maz. Cat. no. 334.]

1319. *Poronia rubra*, Mont. Kagosima Bay, Japan. [*Vide* Maz. Cat. no. 154.] Among sea-weeds and barnacles in 2nd and 3rd levels; rocky shore.

1339. *Natica marochiensis* [? *maroccana*; *v.* Maz. Cat. no. 570]. Kagosima Bay, Japan. Dead on shore.

1344. *Acmæa ? Sieboldi*; very near *patina.* Kagosima Bay, Japan. Rocks at l. w.

1351. *Torinia variegata*, Lam. Kagosima Bay, Japan. [*Vide* Maz. Cat. no. 484.] Dead on shore.

1414. *Nassa gemmulata*, Lam. [non C. B. Ad.] Kagosima Bay, Japan. 5 fm. sd.

1476. *Acar* [*Barbatia*] *gradata*, Brod. and Sby. Taniogesima, Kagosima Bay, Japan. [*Vide* Maz. Cat. no. 194.] Dead in ten fm.; sand and shells.

407,476. *Acar* [*Barbatia*] *gradata*, Brod. and Sby. Port Jackson.

1502. *Lima squamosa*, Lam. Taniogesima, Japan. [=*L. tetrica*, Gld., teste *Cum.*]

The remaining species from these localities are either local or belong to the Philippine and Polynesian fauna. At Simoda and Hakodadi we enter on a mixed fauna.

1574. *Haliotis discus*, Rve. Simoda and Hakodadi. Rocks at low water, four fm. "*Kamtschatkana* seems to be the small growth of the same." [It is locally abundant, however, on the West Coast; while *discus* has never been found there, and is much flatter.]

1577. *Lutraria* [*Schizothærus Nuttallii*, Conr.] Hakodadi Bay. Eight fm. sand.

1579. *Cytherea petechialis*, Lam. Hakodadi Bay. Sand, 4th level.

1582. *Tritonium* [*Chrysodomus*] *antiquum*, Ln. Hakodadi Bay (also Okhotsk and Arctic Oc., 1779). Low-water mark and laminarian zone, on weedy rocks.

1585. *Tritonium* [*Priene*] *Oregonense*, Redf. Hakodadi Bay. Dead on shore, and in twenty fm. Also no. 1955.

1588. *Tellina Bodegensis*, Hds. Hakodadi Bay. Dead on shore.

1589. *Mya arenaria*, Ln. Hakodadi Bay.

1592. *Mercenaria orientalis*, Gld. [A West Atlantic type, probably=*M. Stimpsoni*, Otia, p. 169.] Hakodadi Bay. Six fm. sand.

S.I.Cat. no.
1596. *Venus rigida*, Gld. [MS. non Gld., Otia, p. 85,=*Tapes*, var. *Petitii*. The Japanese shell is *Adamsii*, Rve., from type]. Hakodadi Bay. Four to ten fm. sand.

The above occur in connexion with local and with diffused tropical species.

1601. *Euthria ferrea*, Rve. Simoda. Among stones and pebbles, 3rd level. [Almost identical with the Cape Horn species, *E. plumbea*, Phil.]
1630. *Tritonium* [*Chrysodomus*] *cassidariæformis*, Rve. East Coast of Japan, lat. 37°, and Hakodadi. Twenty fm., black coarse sand.
1632. *Chiton* "largest" [? *Cryptochiton Stelleri*]. Hakodadi. On large stones and under shelving rocks, low-water mark.
1634. *Pecten*, like [=] *Islandicus*. Hakodadi. Ten fm. shell-sand.
1635. *Sanguinolaria Nuttallii*, Conr.,=*decora*, Hds. Hakodadi. "Possibly=*Soletellina obscurata*, Desh." Sand, low-water mark.
1637. *Macoma lata*, "Gmel. in Mus. Cum.,=*calcarea*, Chem.,=*proxima*, Brown,=*sordida*, Couth.,=*Suensoni*, Mörch." Hakodadi. 4th level, sandy mud.
1639. *Litorina Grœnlandica*, Chem. Hakodadi. Rocks, 1st level.
1648. *Cardium pseudofossile*, Rve.,=*blandum*, Gld., perhaps=*Californiensis*, Desh. Hakodadi. Twenty fm. sand.
1651. *Terebratula* [*Waldheimia*] *Grayi*, Desh. Hakodadi. Shelly gravel, 8–15 fm.
1665. *Leda arctica*, Brod. [=*Y. lanceolata*, J. Sby.]. Hakodadi. Sandy mud, 4–12 fm. Seniavine Str., 10–30 fm.
1674. *Drillia inermis*, Hds. Hakodadi. Shelly sand, 4–10 fm.
1700. *Pecten Yessoensis*, Jay. [Probably a var. of *Amusium caurinum*.] Hakodadi. Weedy mud, 4 fm.
1702. *Cardium* (*Serripes*) *Grœnlandicum*. Awatska Bay, Kamtschatka. Mud, 12 fm. Also Avikamcheche Is., Behring Str., and Arctic Ocean.
1703. *Yoldia thraciæformis*, Storer. Hakodadi. Mud, 12 fm.
1704. *Mytilus edulis*. Hakodadi. Also Avikamcheche Is., Behring Str., and Arctic Ocean. Low-water mark, and in 3rd and 4th level.
1705. *Cardium Californiense*, Desh. Hakodadi. Mud, 12 fm. [= no. 1648.]
1706. *Mya truncata*. Hakodadi; also Avikamcheche Is. Mud, 6–15 fm. Also Arctic Ocean, in mud, 30 fm.
1708. *Buccinum glaciale*. Hakodadi, and Straits of Seniavine, at Amincheche Is., Behring Str.
1710. *Tritonium* [*Chrysodomus*] *antiquum*+*deformis*, Rve., and vars. Hakodadi and Avikamcheche Is. Gravel, 4 fm.
1711. *Buccinum tortuosum*, Rve.,=*scalariforme*+vars. Straits of Seniavine.
1714. *Mya ? arenaria*. Hakodadi and Avikamcheche Is.
1715. *Bullia* [*Volutharpa*] *ampullacea*, Midd. Hakodadi. Gravel, 5–6 fm.
1716. *Lanistes lævigata*, Gray (=*discors*, Ln., teste Dkr. in Mus. Cum.). Mud, 20 fm. Hakodadi and Arctic Ocean; common, in nests, 30 fm.; no. 1739.
1717. *Trichotropis multicaudata* [?=*Tr. coronata*, Otia, p. 121: related to *insignis*, Midd., teste A. Ad.]. Hakodadi. Gravelly mud, 15 fm.
1718. [*Lepeta*] *cæca*, var. *concentrica*, Midd. Hakodadi and Arctic Ocean.
1719. *Trichotropis bicarinata*, Sby. Hakodadi. Not uncommon in laminarian zone. Arctic Ocean; common.
1720. *Macoma proxima*, Brown. Hakodadi; mud, 5–25 fm. Awatska Bay. Arctic Ocean; common, no. 1727.
1721. *Macoma edentula*, Brod. and Sby. Hakodadi. Avikamcheche Is.
1722. *Crepidula grandis*, Midd. Hakodadi. Okhotsk, 15 fm.; no. 2002.
1723. *Venus fluctuosa*, Gld., 1841. ?=*astartoides*, Beck, 1849. Hakodadi and Arctic Ocean; not uncommon. Mud, 5–10 fm.
1725. *Cardita* (*Actinobolus*) *borealis*, Conr. Avikamcheche Is., Behring Straits; mud, 5–30 fm. Awatska Bay; 10 fm. mud. Arctic Ocean; common.
1726. *Saxicava pholadis*, L.,=*rugosa*+*distorta*. Avikamcheche Is., Arctic Ocean. Awatska Bay; on shells, &c. Lam. zone; no. 1729.
1728. *Margarita obscura*, Couth. Awatska Bay, Kamtschatka. Mud, 10 fm.
1732. *Bela turricula*., Mont. Awatska Bay; mud, 6-15 fm. Also Seniavine Str.; no. 1782.

S.I.Cat. no.
1733. *Yoldia limatula*, Say. Awatska Bay and Arctic Oc. Mud, common, 5–20 fm.
1734. *Natica clausa*, Brod. Awatska Bay. Mud, 5–15 fm.
1735. *Yoldia myalis* (or *hyperborea*). Awatska Bay. Mud, 10 fm.
1736. *Leda minuta*. Seniavine Str.; Arctic Oc., near Behr. Str. Mud and pebbly sand, 15–30 fm., coarse striæ.
1737. *Leda minuta*, var. Ditto. Mud and pebbly sand, 5–20 fm., fine striæ.
1740. *Modiolaria corrugata*. Ditto. Mud, in nests, 30 fm.
1741. *Rhynchonella psittacea*. Ditto. Gravel and sponges, 20–30 fm.
1742. *Margarita striata*, Leach. Ditto. Shelly gravel, common, 15–30 fm.
1744. *Admete arctica*, Midd. Ditto. Mud, 30 fm.
1745. *Admete viridula*, Couth. Ditto. Gravel, 4 fm.; mud, 10–30 fm.
1747. *Velutina haliotoidea*. Ditto. Gravel, 10–25 fm.
1748. *Margarita argentata* [Gld. Inv. Mass.]. Ditto. Mud, 30 fm.; shelly, 15–25 fm.
1749. *Turritella* (sp.), Migh. Ditto. Mud, 30 fm.; clean gravel, 4–20 fm.
1750. *Trichotropis bicarinata*. Ditto. Pebbly mud, 5–6 fm.
1751. *Lunatia pallida*, Brod. Ditto. Mud, 10–30 fm.
1752. *Cylichna triticea*, Couth. Ditto. Mud, 15–30 fm.
1753. *Velutina* [*Morrilia*] *zonata* [Gld. Inv. Mass.]. Ditto. On stones, 5 fm.
1754. *Nucula tenuis*, Mont. Ditto. Mud, common, 20–30 fm.; pebbly mud, 5–20 fm. Also Hakodadi; sandy mud, 10 fm.; no. 1687.
1756. *Trophon clathratus*, Linn. Ditto. Mud, 20–30 fm.; gravel, 4 fm.
1757. *Lunatia septentrionalis*, Beck. Ditto. Gravelly mud, common, 20 fm.; gravel, 4 fm.
1758. *Amicula vestita*, Sby. Ditto. Gravel, common, 10–40 fm.
1759. *Scalaria Grœnlandica*, Chemn. Ditto. Mud, 30 fm.
1760. *Lunatia pallidoides*. Ditto. Mud, 30 fm.
1761. *Chrysodomus Islandicus*, Chemn. Ditto. Mud, 30 fm.
1762. *Patella* [*Lepeta*] *candida*, Couth. Ditto. Mud, 30 fm.
1763. *Chiton albus*, Linn. Ditto. On shells in mud, 30 fm.
1765. *Chrysodomus Schantaricus*, Midd. Ditto. Mud, 20–30 fm.
1770. *Astarte lactea*, Br. and Sby. Arctic Oc. Mud, 30 fm.
1771. *Pecten Islandicus*, Chemn., var. Arctic Oc. Mud, 30 fm.
1773. *Buccinum ?undatum* (probably bicarinate var. of *glaciale*). Arctic Ocean.
1774. *Buccinum ?undatum*, var. *pelagica*. Arctic Ocean.
1775. *Buccinum ?Ochotense*, Midd. Arctic Ocean.
1776. *Buccinum angulosum*, Gray (=*glaciale*, var.). Arctic Ocean.
1777. *Buccinum ? tenue*, Gray. Arctic Ocean.
1778. *Mangelia*, like *simplex*, Midd. Arctic Ocean.
1781. *Bela rufa*, Mont. Seniavine Str. Pebbly mud, common, 5 fm.
1783. *Turritella erosa*. Seniavine Str. Mud, 10–20 fm.
1784. *Lyonsia Norvegica*, Chem. Seniavine Str. Pebbly mud, 5 fm.
1785. *Trichotropis insignis*, Midd. Seniavine Str. Gravel, 10 fm.
1789. *Bela decussata*, Couth. Seniavine Str. Sandy mud, 10–20 fm. Also Awatska Bay; no. 1730.
1790. *Yoldia myalis*, Couth. Seniavine Str. Mud, 10–20 fm.; pebbly mud, 5 fm.
1791. *Bela harpularia*, Couth. Pebbly mud, 5 fm.
1793. *Margarita helicina*, Fabr. Behring Str. Clean gravel and algæ, 5 fm.
1796. *Turtonia* [? *minuta*, Fabr.]. Behring Str. Common on sponges, 20–40 fm.
1798. *Lunatia* [*Acrybia*] *aperta*, Lov. Kamtschatka.
1799. *Modiolaria nigra*, Gray. Arctic Ocean.
1821. *Chama lobata* [=*exogyra*, Jay, non Conr.]. China Sea, west of Formosa. Shell-gravel, 30 fm.
1836. *Purpura emarginata*, Desh. San Francisco. On rocks in 4th level.
1837. *Litorina plena*, Gld. San Francisco. On rocks in 3rd and 4th levels.
1838. *Acmæa textilis*, Gld. San Francisco. On piles and rocks between tides.
1838*b*. *Acmæa patina*, Esch. San Francisco. On piles and rocks between tides.
1839. *Cryptomya Californica*, Conr. San Francisco. On sandy beaches.
1840. *Macoma nasuta*, Conr. San Francisco. Common in sandy mud, l. w. 10 fm.
1841. *Cardium Nuttallii*, Conr. San Francisco. Common in sandy mud, l. w. 10 fm.

S.I.Cat. no.
1843. *Mytilus edulis*, var. San Francisco. On rocks and gravel, 4th level.
1844. *Mytilus Californianus*, Conr. Near entrance to San Francisco. On rocks and gravel, 4th level.
1845. *Tapes diversa*, Sby. San Francisco Bay. Very common, low-water mark [= *V. staminea*, Conr., var., = *V. mundulus*, Rve.; *v. anteà*, p. 570].
1846. *Chiton* [*Mopalia*] *muscosus*, Gld. Entrance of San Francisco Bay. Not uncommon on rocks at low-water mark.
1847. *Cryptodon* [*Schizothærus*] *Nuttallii*, Conr., jun. San Francisco. One sp.
1848. *Machæra lucida*, Conr. San Francisco. Common. [= *M. patula*, Portl.]

The shells brought back by the Expedition from Puget Sound and Shoalwater Bay were collected by Dr. Cooper, whom Dr. Stimpson met at San Francisco, and are not here catalogued, as they appear again in his own collections, *v. infra*, par. 101.

1860. *Lithophagus cinnamomeus*. China coast, lat. 23½°. Dead, 25 fm., sand.
1924. *Helix tudiculata*, Bin. Petaluma, Cal.; under stems in open grove of scrub oak.
1956. *Mytilus splendens*, Gld. Hakodadi Bay. Rocks below tide-marks, com.
1957. *Anomia olivacea*, Gld. Hakodadi Bay. On shells or gravelly sand, 10 fm.
1958. *Cerastoma foliatum*, var. *Burnettii*, Ad. and Rve. Hakodadi Bay and N. E. part of Niphon. Low-water mark, on rocks and boulders.
1959. *Haliotis Kamtschatkana*, Jonas. N. E. shore of Niphon. See no. 1574.
1960. *Purpura Freycinettii*, Desh. N. E. shore of Niphon. Common on rocks.
1961. *Purpura Freycinettii*, var. with muriciform lamellæ. N. E. shore of Niphon.
1967. *Placunanomia macroschisma*, Desh. West Coast of Jesso. Gravel, 30 fm.
1968. *Terebratula pulvinata*, Gld. Arctic Ocean. Gravel, 30 fm.
2000. *Puncturella noachina*, Linn. Sea of Okhotsk. Gravel, 20 fm.
2001. *Astarte lactea*, Brod. and Sby. Sea of Okhotsk. Gravel, 20 fm.
2003. *Terebratula globosa*, Lam. Sea of Okhotsk. Gravel, 36 fm. [Perhaps *Californica*, Koch.]

The following, from among the new species described by Dr. Gould in his 'Otia Conch.,' belong to the same province, and to forms which may be expected to appear on the northern shores of West America. They were first published in the Proc. Bost. Soc. Nat. Hist., under the dates quoted:—

Otia, p.	Bost. Proc. S.N.H.		
109.	1859.	June.	*Natica severa*, Gld., like *heros*, but with umbilicus resembling *unifasciata*. Hakodadi, W. S.
109.	„	„	*Natica russa*, Gld., like *clausa*. Arctic Ocean, W. S.
115.	„	Dec.	*Patella pallida*, Gld. Hakodadi. On stones and gravel, 10 fm.
115.	„	„	*Patella grata*, Gld. N. E. shore of Niphon.
115.	„	„	*Acmæa dorsuosa*, Gld., like *patina*, var. *monticula* [*monticola*], Nutt. Hakodadi, on rocks of 2nd and 3rd lamin. zone. W. S.
117.	„	„	*Chiton* (*Leptochiton*) *concinnus*, Gld., like *albus*, but with lines of punctures. Hakodadi, W. S.
118.	„	„	*Chiton* (*Acanthochætes*) *achates*, Gld. Kikaia, Hakodadi, W. S.
118.	1859.	Dec.	*Chiton* (*Molpalia*) *Stimpsoni*, Gld., like *Blainvillei*, without anterior radiating lines. ["On stones, clean bottom, 25 fm., and under stones and rocks, low-water mark."—Smiths. Cat. no. 1646. Not to be confounded with *M. Simpsoni*, Gray.] Hakodadi, W. S.
120.	1860.	Sept.	*Terebratula* [? *Waldheimia*] *transversa*, Gld., like *Grayi*, with shorter internal supports: [= *Grayi*, teste A. Ad.] Hakodadi, W. S.
120.	„	„	*Terebratella miniata*, Gld., like *Zelandica*. Apophyses united to central crest. [= *Waldheimia Koreanica*, Ad. and Rve., teste Rve. from type. "On pebbles, clean bottom, 30 fm." Smiths. Cat. 1597.] Hakodadi, W. S.
120.	„	„	*Rhynchonella lucida*, Gld.; in aspect like *T. vitrea*, jun.
121.	„	„	*Trichotropis* (*Iphinoë*) *coronata*, Gld.; like *T. ciliata*, Kruger. Straits of Semiavine, Arctic Ocean, 20 fm. mud. W. S.

Otia, p.	Bost. Proc. S.N.H.		
122.	1860.	Sept.	*Buccinum Stimpsoni*, Gld.; like *undatum*, but quite distinct. Avikamcheche Is., Behring Str., W. S. Arctic Ocean, *Rodgers*. [Not *B. Stimpsonianum*, C. B. Ad.]
123.	„	„	*Neptunea (Sipho) terebralis*, Gld.; like *Icelandica*. Arctic Oc.
125.	„	„	*Trophon incomptus*, Gld.; like *crassus*. Hakodadi, W. S.
134.	„	Oct.	*Bela turgida*, Gld. Kamtschatka, W. S.
153.	1861.	Mar.	*Margarita ianthina*, Gld.; like *Schantarica*. Arctic Ocean.
154.	„	„	*Margarita albula*, Gld.; like an overgrown *arctica*. Arctic Ocean., W. S.
154.	„	„	*Margarita mustelina*, Gld. Hakodadi; low water, W. S.
159.	„	„	*Gibbula redimita*, Gld.; like *nivosa*, A. Ad. Hakodadi, W. S.
162.	„	„	*Lyonsia ventricosa*, Gld.; shorter than *Norvegica*. Hakodadi, 2–6 fm., sandy mud, W. S. ["?= *navicula*, jun." A. Ad.]
162.	„	„	*Lyonsia (Pandorina) flabellata*, Gld.; like *arenosa*. Arctic Ocean, W. S.
162.	„	„	*Theora lubrica*, Gld. Hakodadi; common in mud, 6 fm., W. S.
163.	„	„	*Panopæa fragilis*, Gld. Hakodadi, W. S.
163.	„	„	*Panopæa ?generosa*, var. *sagrinata*. Awatska Bay, Kamtschatka, W. S. ["Epidermis projects ⅛ in., as in *Glycimeris*. Mud, 12 fm." Smiths. Cat. 1701.]
164.	„	„	*Corbula venusta*, Gld. Hakodadi, 5–8 fm., shelly sand, W. S.
165.	„	„	*Solen strictus*, Gld.; like *corneus*. Hakodadi, W. S.
165.	„	„	*Solen gracilis*, Gld. [non Phil.] Hakodadi, sandy beaches, W. S.
165.	„	„	*Machæra sodalis*, Gld.; like *costata*. Hakodadi, W. S.
165.	„	„	*Solemya pusilla*, Gld.; like *velum*. Hakodadi, 5 fm., mud, W.S.
167.	„	„	*Tellina lubrica*, Gld.; like *felix* and *fabagella*. Hakodadi, 6 fm., sandy mud, W. S.
168.	„	„	*Saxidomus aratus*, Gld.; like *V. maxima*, Phil. San Francisco. [Described as 4·5 in. long, yet] smaller than *Nuttallii*. ["Open bays at Sir F. Drake's; l. w., sand." Smiths. Cat. 1842.]
169.	„	„	*Venus (Mercenaria) Stimpsoni*, Gld.; like the Atlantic forms. Hakodadi, 6 fm., W. S.
170.	„	„	*Mysia (Felania) usta*, Gld.; like an *Astarte*. Hakodadi, 8 fm., sandy mud, W. S.
173.	„	Apr.	*Montacuta divaricata*, Gld. Hakodadi, on *Spatangus*-spines, W. S.
175.	„	„	*Nucula (Acila) insignis*, Gld.; like *mirabilis*: [identical, teste A. Ad.] E. Japan, lat. 37°, and Hakodadi, W. S. ["20 fm. black coarse sand."—Smiths. Cat. 1628.]
177.	„	„	*Mytilus coruscus*, Gld.* Hakodadi; common on rocks between tide-marks, W. S. [?=*M. splendens.*, no. 1956.]
177.	„	„	*Pecten lætus*, Gld.; resembles generally *P. senatorius*, is still more like *P. [Amusium] caurinus*. Hakodadi, shelly mud, 10 fm., W. S. [Non *P. lætus*, Gld., in U. S. Expl. Exped. Shells, Otia, p. 95, = *P. Dieffenbachii*, Gray, teste Cuming.]

95. The United States Expedition to Japan, under Commodore M. C. Perry, 1852–4, was not undertaken for scientific purposes; and no special provision was made either for collecting or describing objects of natural history. A large number of shells, however, were obtained, and identified by Dr. Jay of New York. In Vol. II. of the 'Narrative of the Expedition, &c.' (Washington, 1856, pp. 289–297) is given a list of Japanese shells, with descriptions and figures of the (supposed) new species. The following are related to the molluscs of the West Coast †. Specimens of the most important may be seen in the Cumingian Collection.

* The *M. mutabilis*, described on the same page from Kagosima, is a *Septifer*; it is presumed that the learned author did not open a specimen.

† The student should also consult, for related forms, the 'Mollusca Japonica' by Dr. W. Dunker, Stuttgart, 1861;—like all the other works of the same author, most valuable for the patient care, accurate judgment, and enlarged experience displayed; but relating chiefly to the subtropical portion of the fauna.

Page.	Pl.	Fig.	
292.	1.	7,10.	*Mya Japonica*, n. s. Volcano Bay, Is. Yedo. Closely related to *M. arenaria*: [identical, teste A. Ad.].
292.	1.	8,9.	*Psammobia olivacea*, n. s. Bay of Yedo. [Nearly allied to *Hiatula Nuttalli.*]
293.	4. 3.	1,2. 3,4.	*Pecten Yessoensis*, n. s. Hakodadi. [Resembles *Amusium caurinum*, Gld.]
295.	5.	16,17.	*Purpura septentrionalis*, Rve. [= *P. crispata*, var.] ? Japan.
295.	5.	13,15.	? *Bullia Perryi*, n. s. Bay of Yedo, one sp. dredged. [= *Voluth-harpa ampullacea*, Midd.]
296.			*Venerupis Nuttalli*, Conr. [*Saxidomus*]. Japan.
296.			*Tellina secta*, Conr. Japan.
296.			*Tapes decussata*, Ln. [Probably *T. Petitii*, var. or *Adamsii*. Japan.]
296.			*Ostrea borealis*, Ln. Japan.
296.			*Ianthina communis*, Lam. Japan.
296.			*Ianthina prolongata*, Blainv. Japan.

96. At the time that Dr. Gould was describing Dr. Stimpson's Japanese shells in the Boston Proc. Ac. N. S., Mr. A. Adams, R.N., one of the learned authors of the 'Genera of Recent Mollusca,' was making extensive and accurate dredgings in the same seas. The new genera and species have been and are being published, in a series of papers, in the Ann. & Mag. Nat. Hist. and in the Proc. Zool. Soc., preparatory to an intended complete work on the mollusc-fauna of the Eastern North Pacific. The collections of Mr. Adams have already displayed the Japanese existence of several species, as *Siphonalia Kellettii*, *Solen sicarius*, *Homalopoma sanguineum*, &c., before supposed to be peculiar to the West coast. Unfortunately for our present purpose, while the comparison of specimens was going on, Mr. Adams was unexpectedly called to service on board H.M.S. 'Majestic,' and was obliged to pack up his collections. Enough has been ascertained, however, to prove that it will be unsafe henceforth to describe species from either coast without comparison with those of the opposite shores.

97. *Pacific Railroad Reports.*—As it is necessary, in studying any fauna, to make comparisons far round in space, so it is essential to travel far back in time. The fullest account of the fossils of the West Coast of America is to be found in the 'Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean,' which form ten thick quarto volumes, copiously illustrated with plates, and published by the U.S. Senate, Washington, 1856 *. The natural-history department was conducted under the superintendence and with the aid of the Smithsonian Institution; and science is under special obligations to Prof. Spencer S. Baird, the Assistant Secretary, for his Reports on the Vertebrate Animals. It would hardly be expected in Europe that the best *résumé* of the zoology, the botany, and the geology of the vast region between the Great American desert and the Pacific should be found in a railroad survey. Unfortunately, it has not been the custom to advertize and sell the valuable documents printed at the expense of the U. S. Government, in the ordinary channels of trade. They often become the perquisites of the members of Congress, and through them of the various *employés*, by whom they are transferred to the booksellers' shelves. The fifth volume of the series is devoted to the explorations of Lieut. Williamson; the second Part contains the Report by W. P. Blake, geologist and mineralogist of the expedition. In the Appendix, Art. II., are found "Descriptions of the Fossil Shells," by T. A. Conrad. They were first published in the

* This extremely costly and valuable assemblage of documents was selling in Washington, in 1860, at £5 sterling the set.

'Appendix to the Preliminary Geological Report,' 8vo, Washington, 1855. They are divided into, I. "Eocene," and II. "Miocene and Recent Formations."

I. *Eocene* (all from Cañada de las Uvãs*).

Plate.	Fig.	No.	
II.	1.	1.	*Cardium linteum*, Conr., n.s. Allied to *C. Nicolleti*, Conr.
,,	2.	2.	*Dosinia alta*, Conr., n.s.
,,	3.	3.	*Meretrix Uvasana*, Conr., n.s.
,,	4.	4.	*Meretrix Californiana*, Conr., n.s. Allied to *M. Poulsoni*, Conr.
,,	5.	5.	*Crassatella Uvasana*, Conr., n.s.
		6.	*Crassatella alta*, Conr., n.s. In small fragments, but abundant, as at Claiborne, Al.
,,	10.	7.	*Mytilus humerus*, Conr., n.s.
,,	6.	8.	*Cardita planicosta*, Lam., = *Venericardia ascia*, Rogers. First discovered in Maryland in 1829, by Conr.; occurs abundantly in Md., Va., Al., and is quite as characteristic of the American as of the European Eocene period.
,,	7.	9.	*Natica ? œtites*, Conr., 1833.
,,	7.	10.	*Natica ? gibbosa*, Lea, 1833, or *N. semilunata*, Lea; also found at Claiborne, Al.
,,	8.	11.	*Natica alveata*, Conr., n.s.
,,	12.	12.	*Turritelia Uvasana*, Conr., n. s. Allied to *T. obruta*, Conr., = *T. lineata*, Lea, from Claiborne, Al.
,,	9.	13.	*Volutatithes* [? *Volutilithes*] *Californiana*, Conr., n.s. Resembles *V. Sayana*, Conr.
,,	13.	14.	? *Busycon Blakei*, Conr., n.s.
,,	11.	15.	*Clavatula Californica*, Conr., n.s. Allied to *C. proruta*, Conr., of Claiborne Eocene.

II. *Miocene and Recent Formations* (from various localities).

III.	15.	16.	*Cardium modestum*, Conr., n.s. San Diego. [May be *Hemicardium biangulatum*, jun.]
,,	19.	17.	*Nucula decisa*, Conr., n.s. Resembles *N. divaricata* of the Oregon Miocene. [Closely allied to *N. castrensis*, &c., but too imperfect to determine.] San Diego.
III.	16.	18.	*Corbula Diegoana*, Conr., n.s. San Diego.
,,	20.	19.	*Meretrix uniomeris*, Conr., n.s. Monterey Co.
,,	27.	20.	*Meretrix decisa*, Conr., n.s. Ocoya Creek.
,,	22.	21.	*Meretrix Tularena*, Conr., n.s., [in list, "*Tularana*" in text]. From a boulder in Tulare Valley. [Comp. *Tapes gracilis*, Gld.]
,,	28.	22.	*Tellina Diegoana*, Conr., n.s., San Diego.
,,	14, 18 & 21	23.	*Tellina congesta*. Conr., n.s. [Appears a *Heterodonax*, allied to *bimaculata*, Lam.] Abundant at Monterey, Carmello, and San Diego.
,,	17.	24.	*Tellina Pedroana*, Conr., n.s. [? = *T. gemma*, Gld.] Recent formation. San Pedro.
,,	29.	25.	*Arca microdonta*, Conr., n.s. Resembles *A. arata*, Say, of the Maryland Miocene. Miocene, ? Tulare Valley.

* The existence of Eocene strata on the Pacific slope is ascertained by a single boulder of very hard sandstone, which, though very small, furnished fifteen species. Of these, three correspond with forms from Claiborne, Alabama; and the "finger-post of the Eocene" appears in its usual abundance. Mr. Conrad characterizes the specimens as "beautifully perfect;" which would not have been supposed from his descriptions and figures. They "seem to indicate a connexion of the Atlantic and Pacific Oceans during the Eocene period;" and the author expects that "when the rock shall have been discovered and investigated *in situ*, fresh forms will be obtained, with which we are already familiar in eastern localities."

Plate	Fig.	No.	
IV. (III. in text).	31.	26.	*Tapes diversum*, Sby. [= *Tapes staminea*, Conr., var. *Petitii*, Desh.] Recent formation. San Pedro.
III.	25.	27.	*Saxicava abrupta*, Conr., n.s. [Probably the shortened form of *Petricola carditoides*, Conr.] Recent formation. San Pedro.
"	24.	28.	*Petricola Pedroana*, Conr., n.s. [Allied to *P. ventricosa*, Desh.] Recent formation San Pedro.
IV.	33.	29.	*Schizothærus Nuttalli*, Conr., "n.s." = *Tresus capax*, Gld. Recent formation. San Pedro.
III.	23.	30.	?*Lutraria Traskei*, Conr., n.s. [Not improbably = *Saxidomus Nuttallii*, Conr., jun.] ?Miocene. Carmello.
V.	45.	31.	*Mactra Diegoana*, Conr., n.s. Like *M. albaria*, of the Oregon Miocene. [Resembles *Mulinia angulata*, Gray.] ? Miocene. San Diego.
"	35.	32.	*Modiola contracta*, Conr., n.s. [Very like *M. recta*, Conr.] ? Miocene. Monterey Co. Recent formation.
"	40.	33.	*Mytilus Pedroanus*, Conr., n.s. [Probably = *M. edulis*, jun.] Recent formation. San Pedro.
"	41.	34.	*Pecten Deserti*, Conr., n.s. [Resembles *P. circularis.*] Miocene. Carrizo Creek, Colorado Desert.
"	34.	35.	*Anomia subcostata*, Conr., n.s. [? = *Placunanomia macroschisma.*] Miocene. Colorado Desert. Allied to *A. Ruffini.*
"	36–38.	36.	*Ostrea vespertina*, Conr., n.s. [Resembles *O. lurida*, var.] Miocene. Colorado Desert. Like *O. subfalcata*, Conr.
		37.	*Ostrea Heermanni*, Conr., n.s. Colorado Desert.
"	43.	38.	*Penitella spelæa*, Conr., n.s.* Recent formation. San Pedro.
"	44.	39.	*Fissurella crenulata*, Sby. [= *Lucapina c.*] Recent formation. San Pedro.
VI.	52.	40.	*Crepidula princeps*, Conr., n.s. [= *C. grandis*, Midd.] Recent formation. Santa Barbara.
V.	39.	41.	*Narica Diegoana*, Conr., n.s. ? Miocene. San Diego.
"	42.	42.	*Trochita Diegoana*, Conr., n.s. [Like *T. ventricosa*; but may be *Galerus contortus.*] ?Miocene. San Diego.
"	46.	43.	*Crucibulum spinosum*, Conr., n.s.† Recent formation. San Diego.
VI.	49.	44.	*Nassa interstriata*, Conr., n.s. [= *N. mendica*, Gld.]. Recent formation. San Pedro.
"	48.	45.	*Nassa Pedroana*, Conr., n.s. [Comp. *Amycla gausapata* and its congeners.] ‡ Recent formation. San Pedro.
"	51.	46.	*Strephona Pedroana*, Conr., n.s. [Comp. *Olivella bætica.*] Recent formation. San Pedro.
"	50.	47.	*Litorina Pedroana*, Conr., n.s. [= *L. plena*, Gld.] Recent formation. San Pedro.
"	47.	48.	*Stramonita petrosa*, Conr., n.s. [Is perhaps *Monoceros lugubre.*] ?—. Tulare Valley.

* Mr. Conrad regards the "coriaceous cup as characteristic of the genus." It appears a subgenus of *Pholadidea*, differing in the form of the plate. Mr. Tryon, "Mon. Pholad.," p. 66, restricts it to the *Penitella penita*, which (according to his diagnosis) has one central and two anterior dorsal plates. The closely related *P. ovoidea* he leaves in the original genus, as having "two dorsal accessory valves," although he allows that "its position cannot be accurately determined on account of the loss of its dorsal valves." Conrad's fossil has the shape of *P. ovoidea*; but although he says that it is "widely distinct" from *P. penita*, I am unable to separate it from the ovoid form of that species, which will be found in the Smithsonian series.

† This is certainly Sowerby's species, to which Conrad gives a doubting reference. In the text he gives it as "*spinosum*, Conr.," in his table marking it as "nov. sp."

‡ Conrad compares *N. interstriata* to *N. trivittata*, Say, and *N. Pedroana* to *N. lunata*, Say, and states that the two Atlantic species are "associated with each other both in the sea and in the Miocene deposits of Virginia and Maryland." As the two correlative species are found together, living and fossil, on the Pacific side, there is presumptive evidence for their having descended from a common stock.

Plate.	Fig.	No.	
VI.	54.	49.	?*Gratelupia mactropsis*, Conr., n.s. [?=*Donax punctatostriatus.*] ?Miocene. Isthmus of Darien. Resembles *G. Hydeana*, Conr. Eocene.
„	55.	50.	*Meretrix Dariena*, Conr., n.s. [Comp. *Cyclina subquadrata.*] ?Miocene. Isthmus of Darien.
„	53.	51.	*Tellina Dariena*, Conr., n.s. ?Miocene. Isthmus of Darien.
VII.	57.	52.	*Natica Ocoyana*, Conr., n.s. [Marked 51 on plate: err.] Ocoya or Posé Creek.
„	67.	53.	*Natica geniculata*, Conr., n.s. Ocoya Creek. Resembles *N. alveata.*
„	62.	54.	*Bulla jugularis*, Conr., n.s. Ocoya Creek.
„	69.	55.	*Pleurotoma transmontana*, Conr., n.s. [Marked 60 on plate: err. Closely resembles *Chrysodomus dirus*, Rve.] Ocoya Creek.
		56.	*Pleurotoma Ocoyana*, Conr., n.s. [Omitted in the text.] Ocoya Cr.
„	72.	57.	*Syctopus* [Ficula.] *Ocoyanus*, Conr., n.s. Ocoya Creek.
VIII.	73.	58.	*Turritella Ocoyana*, Conr., n.s. Ocoya Creek.
„	76.	59.	*Colus arctatus*, Conr., n.s. Ocoya Creek.
„	75.	60.	*Tellina Ocoyana*, Conr., n.s. Ocoya Creek.
„	77.	61.	*Pecten Nevadanus*, Conr., n.s. Very like *N. Humphreysii*, Maryland, Miocene. Ocoya Creek.
IX.	83.	62.	*Pecten calilliformis*, Conr., n.s. Very like *P. Madisonius*, Say, Virginia, Miocene. Ocoya Creek.

The following species are not described in the text, but quoted in the list. *Vide* p. 320:—

VIII.	?78.	63.	*Cardium*, sp. ind. Ocoya Creek.
		64.	*Arca*, sp. ind. Ocoya Creek.
„	?80.	65.	*Solen*, sp. ind. Ocoya Creek.
„	?81.	66.	*Dosinia*, sp. ind. Ocoya Creek.
„	?79.	67.	*Venus*, sp. ind. Ocoya Creek.
		68.	*Cytherea ?decisa*, Conr. Ocoya Creek.
		69.	*Ostrea*, sp. ind. San Fernando.
		70.	*Pecten*, sp. ind. San Fernando.
		71.	*Turritella biseriata*, Conr., ?n.s. San Fernando.
VII.	?58.	72.	*Trochus*, sp. ind. Benicia.
„	?59.	73.	*Turritella*, sp. ind. Benicia.
„	?71.	74.	*Buccinum ?interstriatum.* San Pedro.
	*	75.	*Anodonta Californiensis*, Lea. Colorado Desert.

Mr. Conrad, than whom there is no higher authority for American Tertiary fossils, considers the age of the Eocene boulder ascertained; and that "the deposits of Santa Barbara and San Pedro represent a recent formation, in which (*teste* Blake) the remains of the Mammoth occur: and the shells indicate little, if any, change of temperature since their deposition." But he acknowledges that the intermediate beds are of uncertain age. Those on Carrizo Creek he refers to the Miocene, some characteristic species being either identical with the Eastern Miocene or of closely related forms. In addition to the species tabulated in this Report, he quotes, as having been collected in California by Dr. Heermann, "*Mercenaria perlaminosa*, Conr., scarcely differing from *M. Ducatelii*, Conr.; and a *Cemoria*, *Pandora*, and *Cardita* of extinct species, closely analogous to Miocene forms." The casts from Ocoya Creek were too friable to be preserved, and are figured and described from Mr. Blake's drawings; these also are regarded as Miocene. The San Diegan specimens are too imperfect for identification; they are referred to the Miocene by Conrad, but may perhaps be found to belong to a later

* Several fossils are figured in plates vii. and viii., to which no reference is made in the text. It is unsafe to conjecture the genus to which many of them belong, but it is presumed that they relate to the indeterminate species here quoted.

age. The types of these species in the Smithsonian Museum appear too imperfect to determine specifically with any confidence; and by no means in a suitable condition to allow of important conclusions being drawn from them.

98. The third article in the Appendix to the same volume of Reports contains a "Catalogue of the Recent Shells, with Descriptions of the New Species," by Dr. A. A. Gould. The specimens were (apparently) in the hands of Dr. Gould for examination when he prepared the MS. for the first Report; and some of them were included in the "Mexican War Collections," B. A. Report, pp. 227, 228. "The freshwater shells were collected in the Colorado desert and other localities; the land and marine shells between San Francisco and San Diego." The following is the list of species as determined by Dr. Gould, pp. 330–336. The specimens belong to the Smithsonian Institution, where a large portion of them were fortunately discovered and verified. They were collected by W. P. Blake, Esq., and Dr. T. H. Webb.

Plate.	Fig.	No.	
		1.	*Ostrea*, sp. ind. Parasitic on twigs; thin, radiately lineated with brown. [= *O. conchaphila*, Cpr.] Another species, elongated, solid, allied to *Virginica* [var. *rufoides*]. San Diego.
		2.	*Pecten monotimeris*, Conr. San Diego.
		3.	*Pecten ventricosus*, Sby.,+*tumidus*, Sby. [Dead valves, of the form *æquisulcatus*.] San Diego.
		4.	*Mytilus ?edulis* [= *M. trossulus*, Gld., *anteà*]. San Francisco.
		5.	*Modiola capax*, Conr. San Diego.
		6.	*Venus Nuttallii*, Conr. [= *V. succincta*, Val.] San Pedro.
		7.	*Venus fluctifraga*, Sby. San Diego.
		8.	*Tapes grata*, Say, = *T. discors*, Sby., "= *straminea*, Conr."* San Pedro.
XI.	19,20.	9.	*Tapes gracilis*, Gld., n.s. Prel. Rep. 1855. [Quite distinct from every other *Tapes* known from the coast. It is supposed by Dr. Cooper to be the young of *Saxidomus aratus*, which in shape and pattern exactly accord with the figure and diagnosis. But the "*Tapes*" is figured without sculpture. The shell was not found at the Smiths. Inst.] San Pedro, *Blake*.
		10.	*Cyclas*, sp. ind. Colorado Desert.
XI.	21,22.	11.	*Cardium cruentatum*, Gld., n.s. Prel. Rep. 1855. [P. Z. S. 1856, p. 201, = *C. substriatum*, Conr.] San Diego. [San Pedro, *Blake*, in text.]
		12.	*Lucina orbella*, Gld. [= "*Mysia* (*Sphærella*) *tumida*," Conr.] San Pedro.
		13.	*Lucina Nuttallii*, Conr. San Pedro.
		14.	*Mesodesma ?rubrotincta*, Sby.† San Pedro.
		15.	*Tellina vicina*, C. B. Ad. [Dead specimens of = *Heterodonax* ("*Psammobia*," var.) *Pacifica*, Conr.] San Diego.
		16.	*Tellina secta*, Conr. San Pedro.
		17.	*Sphænia* [*Cryptomya*] *Californica*, Conr. San Diego.
		18.	*Petricola carditoides*, Conr., = *cylindracea*, Desh. Monterey; San Pedro.
		19.	*Solecurtus Californiensis*, Conr. San Diego.
		20.	*Gnathodon Lecontii*, Conr., = *G. trigonum*, Petit. Colorado Desert. [*Lecontei* is probably the large Texan species: *trigonus* = *mendicus* is a very distinct shell from Mazatlan.]

* Neither Dr. Gould, nor Conrad himself, in his later geological writings, appears to have called to mind the true *T. staminea*, to which the Smithsonian shells belong. It is the northern representative of *T. grata*, but quite distinct: *v.* synonymy under *Venus Petitii* = *rigida*, pars.

† No "*Mesodesma*" was found among the shells returned to the Smithsonian Institution, nor has any been heard-of from the coast. Dr. Gould's shell may have been *Semele pulchra*, which was in the collection.

Plate.	Fig.	No.
		21. *Lottia scabra*, Gld. [non Nutt., Rve.: = *spectrum*, Nutt., Rve.] San Francisco.
		22. *Lottia patina*, Esch. San Pedro.
		23. *Scurria pallida*, Gray, = *Lottia mitra*, Brod. [= *Scurria mitra*, Esch., = *L. conica*, Gld., *anteà*.] San Pedro.
		24. *Calyptræa hispida*, Brod. [= *Crucibulum spinosum*, Sby.] San Pedro; San Diego.
		25. *Crepidula incurva*, Brod.* San Pedro.
		26. *Bulla nebulosa*, Gld. San Diego.
		27. *Bulla* (*Haminea*) *virescens*, Sby. San Diego.
XI.	29.	28. *Bulla* (*Haminea*) *vesicula*, Gld., n.s. Prel. Rep. 1855. [P. Z. S. 1856, p. 203.] San Diego, *Blake*.
XI.	27, 28.	29. *Bulla* (*Tornatina*) *inculta*, Gld., n.s. Prel. Rep. 1855. S. Diego. [P. Z. S. 1856, p. 203. Appears to be a *Utriculus*.]
		30. *Trochus mœstus*, Jonas [= *Chlorostoma funebrale*, A. Ad., = *marginatum*, Nutt. Jonas's species is S. American.] San Diego.
XI.	25, 26.	31. *Phasianella compta*, Gld., n.s. Prel. Rep. 1855. [P. Z. S. 1856, p. 204.] San Diego, *Webb, Blake*.
		32. *Litorina*, sp. ind. [var. *plena*, Gld.] San Diego.
		33. *Melampus*, sp. ind. [*olivaceus*, Cpr.] San Diego.
		34. *Oliva biplicata*, Sby. San Pedro.
XI.	23, 24.	35. *Potamis pullatus*, Gld., n.s. Prel. Rep. 1855. [= *Cerithidea fuscata*, Gld., n.s. P. Z. S. 1856, p. 206. = *C. sacrata*, var., teste Nuttall, Cooper.] San Diego, *Webb, Blake*.
XI.	6–9.	36. *Amnicola protea*, Gld., n.s. Proc. Bost. Soc. N. H., March 1855. Colorado Desert (Gran Jornada), *Webb, Blake*.
XI.	10, 11.	37. *Amnicola longinqua*, Gld., n.s. Proc. Bost. Soc. N. H., March 1855. Colorado Desert (Cienaga Grande), *Blake*.
XI.	12–18.	38. *Planorbis ammon*, Gld., n.s. Proc. Bost. Soc. N. H., Feb. [Otia, Mar. in text] 1855. A very variable species. Colorado Desert and Ocoya Creek, *Webb, Blake*.
XI.	1–5.	39. *Physa humerosa*, Gld., n.s. Proc. Bost. Soc. N. H., Feb. 1855. Colorado Desert, *Blake*; Pecos River, *Webb*.
		40. *Succinea*, sp. ind. Ocoya Creek.
		41. *Helix Vancouverensis*, Lea. San Francisco.
		42. *Helix San-Diegoensis*, Lea. Point Reyes. [No such species, teste Binney.]
		43. *Helix infumata*, Gld. [Otia, p. 215.] Point Reyes.
		44. *Helix Oregonensis*, Lea. Cypress Point.

99. The fossils of the various Western expeditions were being arranged in 1860 in the Smithsonian Museum by Prof. J. S. Newberry, M.D., a naturalist of rare experience and accomplishments, and author of "Reports on the Geology, Botany, and Zoology of Northern California and Oregon." Washington, 1857. They are embodied in vol. vi. of the 'Pacific Railroad Reports.' The following is a list of the fossils, which were described by Mr. Conrad in pp. 69–73, having first appeared in the Proceedings of the Academy of Natural Sciences, Philadelphia, Dec. 1856, to which page-references are added.

Dr. Newberry's Californian Fossils.

Page.	Plate.	Fig.
69.	II.	1. *Schizopyga Californiana*, Conr., Phil. Proc. Dec. 1856, p. 315. [Partaking of the characters of *Cancellaria* and *Pyramidella*.] Santa Clara, Cal.
"	"	2. *Cryptomya ovalis*, Conr., p. 314. [Closely approaching the recent species, *C. Californica*.] Monterey Co.
"	"	3. *Thracia mactropsis*, Conr., p. 313. Monterey Co.

* The *Crepidulæ* returned in this collection were *adunca* and ?*rugosa*, var.

Page.	Plate.	Fig.	
70.	II.	4.	*Mya Montereyana*, Conr., p. 313. [Figure resembles *Periploma argentaria.*] Monterey Co.
,,	,,	5.	?*Mya subsinuata*, Conr. [Comp. *Macoma inquinata.*] Monterey Co.
,,	,,	6.	*Arcopagia medialis*, Conr., p. 314. Like *A. biplicata*, Conr., of the Maryland Miocene. [Closely resembles *Lutricola alta*, Conr.] Monterey Co.
,,	,,	7.	*Tapes linteatum*, Conr., p. 314. California.
,,	,,	8.	*Arca canalis*, Conr., p. 314. Santa Barbara.
,,	,,	9.	*Arca trilineata*, Conr., p. 314. Santa Barbara.
,,	,,	10.	*Arca congesta*, Conr., p. 314. California.
71.	III.	11.	*Axinæa Barbarensis*, Conr. [Closely resembles *Pect. intermedius.*]
,,	,,	12.	*Mulinia densata*, Conr., p. 313. ? Santa Barbara and shores of Pablo Bay.
,,			*Dosinia longula*, Conr., p. 315. Monterey.
,,	,,	13.	*Dosinia alta*, Conr., p. 315. Monterey.
,,	,,	14.	*Pecten Pabloensis*, Conr. San Pablo Bay.
,,	,,	15.	*Pallium Estrellanum*, Conr., p. 313. Estrella Valley.
,,	,,	16.	*Janira bella*, Conr., p. 312. Santa Barbara.
72.	IV.	17.	*Ostrea Titan*, Conr., Phil. Proc. 1855. San Luis Obispo.
	V.	17*a*.	
73.	V.	25.	*Pandora bilirata*, Conr., p. 267. [Closely resembles *Kennerlia bicarinata.*] Santa Barbara.
,,	,,	24.	*Cardita occidentalis*, Conr., 1855, p. 267. [?= *C. ventricosa*, Gld.] Santa Barbara.
,,	,,	23.	*Diadora crucibuliformis*, Conr., 1855, p. 267. [?= *Puncturella cucullata*, Gld.] Santa Barbara.

Fossils of Gatun, Isthmus of Darien.

72.	V.	22.	*Malea ringens*, Swains. Gatun.
,,	,,	19.	*Turritella altilira*, Conr. Gatun.
,,	,,	20.	*Turritella Gatunensis*, Conr. Gatun.
,,	,,	20.	*Triton*, sp. ind. Gatun.
,,	,,	21.	?*Cytherea Dariena*, Conr. [The figure does not appear conspecific with that in the Blake collection, no. 50.] Galun.

The northern fossils are supposed by Mr. Conrad to be of the Miocene period, and not to be referable to existing species. Those from Sta. Barbara, however, are clearly of a very recent age, and probably belong to the beds searched by Col. Jewett. But by far the most interesting result of Dr. Newberry's explorations was the discovery of the very typical Pacific shell, *Malea ringens*, in the Tertiary strata on the Atlantic slope of the Isthmus of Darien, not many miles from the Caribbean Sea. The characters of this shell being such as to be easily recognized, and not even the genus appearing in the Atlantic, it is fair to conclude that it had migrated from its head waters in the Pacific during a period when the oceans were connected. We have a right, therefore, to infer that during the lifetime of existing species there was a period when the present separation between the two oceans did not exist. We may conclude that species as old in creation as *Malea ringens* may be found still living in each ocean; and there is, therefore, no necessity for creating "representative species," simply because, according to the present configuration of our oceans, we do not see how the molluscs could have travelled to unexpected grounds.

100. In vol. vii. of the Pacific Railroad Reports, part 2, is the Geological Report, presented to the Hon. Jefferson Davis, then Secretary of War, by Thos. Antisell, M.D. He states reasons for believing that during the Eocene period the Sierra Nevada only existed as a group of islands; that its final uplifting was *after the Miocene period*; and that during the whole of that

period the coast-range was entirely under water. The Miocene beds are above 2000 feet in thickness, and abound in fossils generally distinct from those of the eastern strata. There is nothing in California answering to the Northern Drift of the countries bordering on the Atlantic. The molluscs of Dr. Antisell's Survey were described by Mr. Conrad, pp. 189–196. He remarks that "the fossils of the Estrella Valley and Sta. Iñez Mountains are quite distinct from those of the Sta. Barbara beds, and bear a strong resemblance to the existing Pacific fauna. The Miocene period is noted, both in the eastern and western beds, for the extraordinary development of *Pectinidæ*, both in number, in size, and in the exemplification of typical ideas." It also appears to be peculiarly rich in *Arcadæ*, which are now almost banished from that region, while they flourish further south. The large *Amusium caurinum* and the delicate *Pecten hastatus* of the Vancouver district, as well as the remarkable *Janira dentata* of the Gulf, may be regarded as a legacy to existing seas from the Miocene idea; otherwise the very few Pectinids which occur in collections along the whole West Coast of North America is a fact worthy of note. Mr. Conrad has "no doubt but that the Atlantic and Pacific oceans were connected at the Eocene period;" and the fossils here described afford strong evidence that the connexion existed during the Miocene epoch. All the species here enumerated (except *Pecten deserti* and "*Anomia subcostata*") were believed to be distinct from those collected by the preceding naturalists.

Dr. Antisell's Californian Fossils.

Page.	Plate.	Fig.	
190.	II. [I. err. typ.]	1, 2.	*Hinnites crassa*, Conr. [? = *H. gigantea*, Gray.] Sta. Margarita.
,,	I.	1.	*Pecten Meekii*, Conr. San Raphael Hills.
,,			*Pecten deserti*, Conr. Blake's Col., p. 15. Corrizo Creek.
,,	III.	1.	*Pecten discus*, Conr. Near Sta. Iñez.
191.	I.	2.	*Pecten magnolia*, Conr. [Probably = *P. Jeffersonius*, Say, Virginia.] Near Sta. Iñez.
,,	III.	2.	*Pecten altiplicatus*, Conr. San Raphael Hills.
,,	III.	3, 4.	*Pallium Estrellanum*, Conr. [*Janira.*] Estrella.
,,	I.	3.	*Spondylus Estrellanus*, Conr. [?*Janira.*] Estrella.
192.	V.	3, 5.	*Tapes montana*, Conr. San Buenaventura.
,,	VII.	1.	*Tapes Inezensis*, Conr. Sta. Iñez.
,,	IV.	1, 2.	*Venus Pajaroana*, Conr. Pajaro River.
,,	IV.	3, 4.	*Arcopagia unda*, Conr. Shore of Sta. Barbara and Estrella. [Closely resembles *A. biplicata*; ? = *Lutricola alta.*]
,,	VII.	4.	*Cyclas permacra*, Conr. Sierra Monica. Resembles *C. panduta*, Conr., = *Lucina compressa*, Lea.
,,	VI.	6.	*Cyclas Estrellana*, Conr. Estrella.
,,	V.	1.	*Arca Obispoana*, Conr. San Luis Obispo.
193.	V.	2, 4.	*Pachydesma Inezana*, Conr. [Like *P. crassatelloides.*] Sta. Iñez Mts.
,,	VI.	1, 2.	*Crassatella collina*, Conr. Sta. Iñez Mts.
,,	II.	3.	*Ostrea subjecta*, Conr. "May be the young of *O. Panzana.*" Sierra Monica.
,,	II.	4.	*Ostrea Panzana*, Conr. Panza, Estrella, and Gaviote Pass.
,,			*Dosinia alta*, Conr. Salinas River.
,,	VII.	2.	*Dosinia longula*, Conr. Salinas River.
194.	VI.	4.	*Dosinia montana*, Conr. Salinas River.
,,	VI.	5.	*Dosinia subobliqua*, Conr. Salinas River. Also a small *Venus*, a *Natica*, and a *Pecten.*
,,	VIII.	2, 3.	*Mytilus Inezensis*, Conr. Sta. Iñez.
,,	V.	6.	*Lutraria transmontana*, Conr. Allied to *L. papyria*, Conr. Los Angeles; also San Luis.

Page.	Plate.	Fig.	
194.	VI.	3.	*Axinea Barbarensis*, Conr. Los Angeles. [?=*intermedius.*]
„	VII.	3.	?*Mactra Gabiotensis*, Conr. Gaviote Pass. May be a *Schizodesma*. Associated with *Mytilus* sp. and *Infundibulum Gabiotensis*.
„	VII.	5.	*Glycimeris Estrellanus*, Conr. Panza and Estrella Valleys. Allied to *Panopæa reflexa*, Say. [?=*P. generosa*, Gld.]
195.			*Perna montana*, Conr. S. Buenaventura. Allied to *P. maxillata*.
„	VII.	3.	*Trochita costellata*, Conr. Gaviote Pass.
„	VIII.	4.	*Turritella Inezana*, Conr. Sta. Iñez Mts.
„	VIII.	5.	*Turritella variata*, Conr. Sta. Iñez Mts.
„	X.	5, 6.	*Natica Inezana*, Conr. [?*Lunatia Lewisii.*] Sta. Iñez Mts.

As before, the fossils appear to be in very bad condition. The succeeding palæontologists who have to identify from them are not to be envied. Their principal value is to show what remains in store for future explorers. The extreme beauty of preservation in the fossils collected by Col. Jewett, rivalling those of the Paris Basin, and sometimes surpassing the conspecific living shells, makes us astonished that so large a staff of eminent men, employed by the Government, made such poor instalments of contribution to malacological science. The plan, too often followed, of remunerating naturalists, not according to the skilled labour they bestow, but according to the number of "new species" they describe, is greatly to be deprecated. Further knowledge concerning the old species may be more important in scientific inquiries than the mere naming of new forms. It is generally a much harder task to perform, and, therefore, more deserving of substantial as well as of honourable acknowledgment.

101. The shells collected on the North Pacific Railroad Survey were intrusted to W. Cooper, Esq., of Hoboken, New Jersey, for description: Dr. Gould being occupied with preparing the diagnoses of the N. Pacific E. E. species. Judge Cooper was at that time the only naturalist in America known to be actively engaged in studying the marine shells of the West Coast, of which he has a remarkably valuable collection. He had rendered very valuable service to the Smithsonian Institution by naming their specimens. Unfortunately, there is such great difficulty even in New York city (of which Hoboken is a suburb) in obtaining access to typically named shells, as well as to many necessary books *, that, notwithstanding the greatest care, errors of determination are almost sure to arise.

The "Report upon the Mollusca collected on the Survey, by Wm. Cooper," forms No. 6 of the Appendix, pp. 369–386, and *errata*. (Unfortunately the

* Both Judge Cooper and Dr. Lea informed me (1860) that they had not been able even to see a copy of the plates to the U. S. Expl. Exped. Mollusca. Through special favour, I was enabled to obtain a series of the proofs to work by. The Smithsonian Institution, though intrusted with the keeping of the collections, was not favoured with a copy until after the war began, when the whole series was granted by Congress. Senator Hale, of New Hampshire, is reported to have spoken and voted for the motion "in order that the two greatest humbugs (viz. the Exploring Expedition and the Smithsonian Institution) might go together." Judge Cooper had derived great assistance from the British Association Report, and has communicated many corrections in it. In the alterations of synonymy, and in defining the limits of specific variation, I have had the benefit of his counsel and experience; and have rarely felt compelled to differ from him. Having himself collected extensively in the West Indies, he had excellent opportunities of comparing fresh specimens from the now separated oceans. I was fortunate enough to meet his son, Dr. J. G. Cooper, at the Smithsonian Institution, and to examine the types of the species he collected (which are here enumerated) with the advantage of his memory and knowledge. His later contributions to the malacology of W. America will be afterwards enumerated: his valuable Treatise on the Forests and Trees of North America will be found in the Smithsonian Reports, 1858, pp. 246–280.

work had been carelessly printed.) It contains the following species, the localities quoted in the text from other sources being here omitted :—

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369. *Murex foliatus,* Gmel.,=*M. monodon,* Esch. (*Cerostoma*). San Diego, ? fossil, *Cassidy.*

„ *Murex festivus,* Hds. Dead. San Diego, *Cassidy.*

„ *Triton Oregonensis,* Redfield (non Jay, nec Say) = *T. cancellatum,* Midd., Rve., non Lam. Straits of De Fuca, *Suckley, Gibbs, J. G. Cooper.*

370. *Chrysodomus antiquus,* var. *Behringiana,* Midd., one specimen. Straits of De Fuca, *Suckley.* [Comp. *Chr. tabulatus.*]

„ *Chrysodomus Middendorffii,* Coop., n. s.,= *Tritonium decemcostatum,* Midd. One specimen on the shore of Whidby's Island. Straits of De Fuca, *J. G. Cooper.* [=*Buc. liratum,* Mart. This being a remarkable instance of a "representative species," it requires to be minutely criticized. Judge Cooper compared his specimen with 130 eastern shells, and noted the differences with great fulness and accuracy. A series of Middendorff's Pacific shells having been brought to England by Mr. Damon, and sold at high prices, I made a searching comparison of one of them with the eastern specimens furnished me by Judge Cooper and other most trusty naturalists. According to the diagnosis of *Middendorffii,* it should be referred to *C. decemcostatus,* Say, and *not* to the De Fuca species, as it agrees in all respects with the eastern peculiarities quoted, except that the riblets near the canal are rather more numerous and defined. As it might be suspected that Mr. Damon's shells were mixed, I have made a similar comparison with a shell from the N. W. coast, sent to the Smiths. Inst. by Mr. Pease, and with the same result. On examining the specimens in the Cumingian Collection, in company with A. Adams, Esq., we were both convinced that the eastern and western forms could not be separated. In the similar shells collected by Mr. Adams in the Japan seas there are remarkable variations in the details of sculpture.]

371. *Chrysodomus Sitchensis,* Midd. [=*incisus,* Gld.,=*dirus,* Rve.]. Str. De Fuca, *Suckley, Gibbs.*

„ *Nassa mendica,* Gld. Puget Sound, *Suckley.*

„ *Nassa Gibbsii,* Coop., n. s. "Resembles *N. trivittata* more than *N. mendica.*" Port Townsend, Puget Sound. [In a large series, neither Dr. Stimpson nor I were able to separate this species from *N. mendica.* Similar variations are common in British *Nassæ.* Picked individuals from the Neeah Bay series would probably be named *trivittata,* if mixed with eastern shells.]

„ *Purpura lactuca,* Esch.,+*M. ferrugineus,* Esch.,= *P. septentrionalis,* Rve. Puget Sound, *Suckley, Gibbs*; Shoalwater Bay, Str. de Fuca, *J. G. Cooper.* "Abounds on rocks and oyster-beds in Shoalwater Bay, the form and amount of rugosity depending on station. The oyster-eaters are smooth even when young."—*J. G. C.*

372. *Purpura ostrina,* Gld.,=*P. Freycinetii,* Midd., non Desh. +*P. decemcostata* [Coop., non] Midd. Rocks above low-water mark; from mouth of Hood's Canal to Str. Fuca; Puget Sound, common, *J. G. Cooper.*

„ *Purpura lapillus* [Coop., non] Linn. [=*P. saxicola,* Val.] Str. De Fuca, Puget Sound, *J. G. Cooper.* "Found with *P. ostrina,* and equally common." [Some varieties run into the New England form of *P. lapillus,* sufficiently nearly to justify the identification; but the bulk of the specimens are easily distinguished by the excavated columella. They pass by insensible gradations to *P. ostrina,* Gld., which is a rare and extreme variety. Many of the shells called *P. Freycinetii* by Midd. are certainly referable to this species. Some forms pass towards the true *P. Freycinetii,* Desh., while others are equally close to the very different *P. emarginata,* Desh.]

„ *Purpura emarginata,* Desh.,=*P. Conradi,* Nutt. MS. "Upper California," *Trask*; San Diego, *Trowbridge.* [This appears to be exclusively a southern form=*saxicola,* var.]

„ *Monoceros engonatum,* Conr.,=*M. unicarinatum,* Sby. San Pedro, *Dr. Trask.*

373. *Monoceros lapilloides,* Conr.,=*M. punctatum,* Gray. San Pedro, *Dr. Trask.*

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373. *Columbella gausapata*, Gld. Str. de Fuca, *Suckley*.
" *Columbella valga* [Cooper, non] Gld. [=*Buccinum corrugatum*, Rve.] Str. de Fuca, *Suckley*.
" *Natica Lewisii*, Gld.,=*N. herculea*, Midd. Puget Sound, *J. G. Cooper*, *Suckley*. "Shell sometimes remarkably globose, sometimes with spire much produced." *W. C.* "Abundant throughout the N.W. sounds, and collected in great numbers by the Indians for food. In summer it crawls above high-water mark to deposit its eggs" in the well-known sand-coils, which are "beautifully symmetrical, smooth, and perfect on both sides."—*J. G. C.*
" *Potamis pullatus*, Gld. A variable species. U. Cal., *Trask*.
374. *Melania plicifera*, Lea. Very common in rivers, W. T., *J. G. Cooper*.
" *Melania silicula*, Gld. [=one of the many vars. of *M. plicifera*, teste Lea]. In rivers, W. T., Nisqually and Oregon, *J. G. Cooper*.
" *Melania Shortaënsis*, Lea, MS. [=*Shastaënsis*, Lea]. Willopah River, *J. G. Cooper*.
" *Amnicola Nuttalliana*, Lea, Phil. Trans. pl. 26. f. 89. Columbia River, *J. G. Cooper*.
" *Amnicola seminalis*, Hds. U. Cal., *Trask*. [Belongs to Dr. Stimpson's new genus, *Fluminicola*.]
" *Turritella Eschrichtii*, Midd. [=*Bittium filosum*, Gld.]. Puget Sound, *Suckley*, *Gibbs*.
" "*Litorina rudis*, Gld., Stn." [Cooper, non Mont.]. Shoalwater Bay, De Fuca, *J. G. Cooper*, *Suckley*, *Gibbs*. "Very abundant on the N.W. coast, where it presents the same varied appearances as our eastern shell."—*W. C.* [To an English eye, it appears quite distinct. *L. rudis*, Coop., with *subtenebrosa*, Midd., and *modesta*, Phil., are probably vars. of *L. Sitkana*, Phil., =*L. sulcata*, Gld.]
" *Litorina scutulata*, Gld. On rocks, from the head of Puget Sound to De Fuca, *J. G. Cooper*.
" *Litorina planaxis*, Nutt. [=*L. patula*, Gld.]. San Luis Obispo, *Dr. Antisell*.
375. *Trochus filosus*, Wood,=*T. ligatus*, Gld.,=*T. modestus*, Midd. Str. de Fuca, *J. G. Cooper*; U. Cal., *Trask*. [=*T. costatus*, Mart.]
" *Trochus Schantaricus* [Coop., non] Midd. [=*Marg. pupilla*, Gld.,=*M. calostoma*, A. Ad.] Str. de Fuca, *J. G. Cooper*, abundant.
" *Haliotis Kamtschatkana*, Jonas. Nootka Sound, *Capt. Russell*, teste Trask.
" *Haliotis corrugata*. San Diego, *Cassidy*.
" *Haliotis splendens*. San Diego, *Cassidy*.
" *Haliotis rufescens*. San Diego, *Cassidy*.
" *Haliotis Cracherodii*. (None of the rare var. *Californiensis*.) S. Diego, *Cassidy*.
" *Fissurella nigropunctata*, Sby. Two specimens sent by Dr. Trask as coming from Catalina Is., U. Cal. [?imported].
" *Fissurella aspera*, Esch.,?=*cratitia*, Gld., ?=*densiclathrata*, Rve. [=*Lincolni*, Gray. This is certainly Gould's species from type; but Reeve's shell is southern, and appears distinct.] U. Cal., *Lieut. Trowbridge*.

376. *Nacella instabilis*.
" *Acmæa pelta*.
" *Acmæa persona*.
" *Acmæa spectrum*.
" *Acmæa scabra*.
" *Acmæa æruginosa*.
" *Scurria mitra*.

The few shells collected of this family are mostly imperfect, but appear to belong to the species quoted: for the synonymy of which, reference is made to the British Association Report.

" *Chiton muscosus*.
" *Chiton submarmoreus*.
" *Chiton tunicatus*.
" *Chiton lignosus*.

Still fewer materials, among which the quoted species were identified. [The "*submarmoreus*," both of Midd. and Coop., may prove to be *Tonicia lineata*, var.] Chiefly from Oregon.

" *Helix fidelis*, Gray,=*Nuttalliana*, Lea. Forests W. of Cascade Mountain, W. T., *J. G. Cooper*.
" *Helix Townsendiana*, Lea. "Common in open prairies near the sea, but not near Puget Sound," W. T., *J. G. Cooper*.

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376. *Helix Columbiana*, Lea,=*labiosa*, Gld. "In wet meadows from Vancouver to the coast, not near Puget Sound," W. T., *J. G. Cooper*.
377. *Helix Vancouverensis*, Lea [+*sportella*, Gld., teste Bland]. "West of Cascade Mountain; most abundant under alder-groves; also on Whidby's Island," W. T., *J. G. Cooper*.
„ *Helix devia*, Gld.,=*Baskervillei*, Pfr. Two sp. in damp woods, near Vancouver, W. T., *J. G. Cooper*.
„ *Helix tudiculata*, Binn. Rare, with the last, Vancouver; also Washington Territory, *J. G. Cooper*.
„ *Succinea Nuttalliana*, Lea. Rare and dead, at Vancouver, *J. G. Cooper*.
„ *Limax Columbianus*, Gld. "Abundant in dense, damp spruce-forests, near Pacific coast; grows to 6 inches, and is smooth, not rugose, when living," *J. G. Cooper*.
378. *Limnæa umbrosa*, Gld. Lake Oyosa, Okanagan River, *J. G. Cooper*.
„ *Limnæa emarginata*, Say. Lake Oyosa, Okanagan River, *J. G. Cooper*.
„ *Limnæa jugularis*, Say. Lake Oyosa, Okanagan River, *J. G. Cooper*.
„ *Physa elongata*, Say. Near Puget Sound, *J. G. Cooper*.
„ *Physa heterostropha*, Say. Ponds in W. T., *J. G. Cooper*.
„ *Physa bullata*, Gld. MS. Lake Oyosa, W. T., *J. G. Cooper*.
„ *Ancylus caurinus*, Coop., ?n. s. ["?=*A. Nuttalli*, Hald.," Coop. MS.] Black River, near Puget Sound, *J. G. Cooper*.
„ *Planorbis corpulentus*, Say. Lake Oyosa, W. T., *J. G. Cooper*.
„ *Planorbis trivolvis*, Say. Exceedingly abundant in shallow lakes near Vancouver, W. T., *J. G. Cooper*.
„ *Planorbis planulatus*, Coop., n. s. "A small carinated species, found only in lakes on Whidby's Island," *J. G. Cooper*. [Comp. *P. opercularis*, Gld.]
379. *Bulla nebulosa*, Gld. Bay of S. Pedro, *Trask*.
„ *Bulla tenella*, A. Ad., in Sby. Thes. pl. 134. f. 104 [?]. Puget Sound, one sp., *Suckley*. [?=*Haminea hydatis*.]
„ *Ostrea edulis*, Coop. [non Linn.:=*O. lurida*, Cpr.]. De Fuca and Puget Sound, *Gibbs*; Shoalwater Bay, *Cooper*. "Small in Puget Sound; finer in Shoalwater Bay, which supplies S. Francisco market; large at Vancouver's Island; very large near mouth of Hood's Canal."
„ [*Placun*]*anomia macroschisma*, Desh. De Fuca, *Gibbs*; Nootka Sound, *Capt. Russell*.
„ *Pecten caurinus*, Gld. De Fuca, *Suckley*. One of the specimens measures 23 inches in circumference and 8 in. across.
380. *Pecten ventricosus*, Sby.,+*tumidus*, Sby. [=?var. *æquisulcatus*, Cpr.]. Upper Cal., *Trask*; San Diego, *Cassidy*.
„ *Mytilus edulis*, Ln. Shoalwater Bay, *Cooper*. "As abundant as in Europe and N. England, with the same variations, and when eaten occasionally causing urticaria."—*J. G. Cooper*.
„ *Mytilus Californianus*, Conr. Puget Sound, Port Townsend, *Suckley*, *Gibbs*; Upper Cal., *Trask*. One specimen is $9\frac{1}{4}$ inches long.
„ *Modiola capax* [Cooper, non] Conr. [=*M. modiolus*, Ln.]. Not common. Str. de Fuca, *Gibbs*, *Cooper*.
„ *Modiola flabellata*, Gld. Puget S. and Str. de Fuca, *Gibbs*. [=*M. recta*, var.]
„ *Lithophagus*, sp. ind., like *falcatus*. [Probably *Adula stylina*, Cpr.] Rocks near mouth of Umpqua River, Oregon, *Dr. Vollum*.
381. *Arca grandis*, Coop. [non Brod. and Sby.,=*A. multicostata*, Sby.]. One sp. living. San Diego, *Cassidy*.
„ *Margaritana margaritifera*, Lea,=*Alasmodonta falcata*, Gld. River Chehalis, &c., W. T., *Cooper*; Shasta River, Or., *Trask*. After careful comparison with eastern U. S. specimens, and those from Newfoundland and Europe, Judge Cooper agrees with Dr. Lea that the N.W. shells are at most a slight variety. "The most abundant of the freshwater bivalves, and the only one yet found in the Chehalis, the streams running into Puget Sound, and most branches of the Columbia. No species is found in the streams running into Shoalwater Bay. Eaten by the Indians E. of the Cascade Mountains," *J. G. C.*

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381\. *Anodonta angulata*, Lea, + *A. feminalis*, Gld. Plentiful in Yakima River, W. T., *Cooper*. A series of specimens of various ages leads Judge Cooper to endorse Dr. Lea's opinion of the identity of the two species.

„ *Anodonta Oregonensis*, Lea. Rivers of W. T., *Cooper*.

„ *Anodonta Wahlamatensis*, Lea. Lagoons in Sacramento River, *Dr. Trask*.

382\. *Cardium Nuttalli*, Conr. Shoalwater Bay and Puget Sound, *Cooper*; San Franc., *Dr. Bigelow, Trask*. "The most abundant clam of Shoalwater Bay, inhabiting sandy mud, a few inches below the surface. The Indians feel for them with a knife or sharp stick with great expertness. In July many come to the surface and die, ? from the sun's heat."

„ *Cardium quadragenarium*, Conr. One valve. San Luis Obispo, *Dr. Antisell*.

„ *Lucina Californica*, Conr. San Diego, *Cassidy*.

„ *Cyclas*, sp. ind. Whidby's Island; pools near Steilacoom, *Cooper*.

„ *Venus staminea*, Conr., + *Venerupis Petitii*, Desh., + *Venus rigida*, Gld. [pars], + *Tapes diversa*, Sby. Shoalwater Bay and Puget Sound, *Cooper, Suckley*; San Francisco, *Trask*; San Diego, *Lieut. Trowbridge*. [To the above synonymy, by Judge Cooper, the large series of specimens in the Smithsonian Mus. compels an assent. He considers *Tapes straminea*, of Sby. Thes., to be a variety of *V. histrionica*, but it more probably = *T. grata*, as Dr. Gould appears to have considered it, having copied Sowerby's error. Conrad named it, not from the colour, as was supposed when quoting it as "*straminea*," but from the thread-like sculpture (teste Conr. ips.). Whatever be the form, colour, or sculpture of the shell, Judge Cooper remarks in all the same characters of teeth and hinge; we may add also, of the pallial sinus.]

383\. *Saxidomus Nuttallii* [Coop., non] Conr., + *Venerupis gigantea*, Desh., + *Venus maxima*, Phil. [?]. Near Copalux River, south of Shoalwater Bay, common at Puget Sound, *Cooper*; Bodegas, Cal., *Trask*. "Much superior to the Atlantic *quahog* as food, but called by the same name. Its station is in somewhat hard sand, near l.-w. mark," *J. G. C.* [Judge Cooper regards all the *Saxidomi* of the coast, except *S. aratus*, as one species. The southern form, "with rough concentric striæ and brown disc," is Conrad's species; "others from Oregon are much smoother, without regular striæ." These are *S. squalidus*, Desh. Dr. Cooper found "a fossil variety, in coast-banks 10 feet above sea-level, which is well figured in Midd. and (less distinctly) by Desh. A Californian specimen measures 4·8 in. across." The fossils, through disintegration, often assume the aspect of *Venus Kennerleyi*, the former margins remaining as varical ridges, while the softer interstices have perished.]

„ *Venus lamellifera*, Conr., = *Venerupis Cordieri*, Desh. San Diego, *Cassidy*.

384\. *Lutraria maxima*, Midd., = *L. capax*, Gld. [= *Schizothærus Nuttalli*, Conr.] Shoalwater Bay, *Cooper*. San Francisco, *Trask*. "Lives buried nearly 2 feet in hard sand, near l. w. mark, its long siphons reaching the surface; also in many parts of Puget Sound up to near Olympia. It is excellent food, and a chief article of winter stores to the Indians, who string and smoke them in their lodges. Length, $7\frac{5}{8}$ in. The burrows are found in the cliffs, 10 feet above high water, with all the other Mollusca now living; and two, not now found, were then common [viz. ?...]. The Indians have no tradition as to the elevation, and the ancient trees show no signs of the irregular upheavings which raised the former levels of low water, by successive stages, to a height now nearly 100 feet," *J. G. C.*

„ *Tellina nasuta*, Conr. Common, from L. Cal. to the Arctic Seas. Shoalwater Bay, *Cooper*; Puget Sound, *Suckley*; San Francisco, *Trask*.

„ *Tellina edentula* [Cpr., Coop., not Brod. and Sby., = *Macoma secta*, var. *edulis*, Nutt.]. Puget Sound, *Gibbs*.

„ *Tellina Bodegensis*, Hds. Shoalwater Bay, rare, *Cooper*; mouth of Umpqua River, *Vollum*.

385\. *Sanguinolaria Californiana*, Conr. "Common at the mouth of the Columbia and other rivers, and high up salt-water creeks," *Cooper*. [= *Macoma inconspicua*, Brod. and Sby.]

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385. *Solen sicarius*, Gld. One dead shell, near Steilacoom, Puget Sound, *Cooper*. "Probably abundant on the mud-flats near the mouth of the Nisqually River," *J. G. C.*

,, *Machæra patula*, Portl. and Dix. (Coop. errata; *Nuttalli* in text), =*Solen maximus*, Wood, non Chemn.,=*Solecurtus Nuttallii*, Conr.,=*Machæra costata*, Midd., non Say. Washington Ter., *Cooper*. "Burrows a few inches from the surface, at the edge of the usual low tide; is justly considered (except the oyster) the best of the many fine eatable molluscs of the coast. It is the only truly marine mollusc found near the Columbia River; extends northwards wherever the beach is sandy, but not known in the Straits of de Fuca," *J. G. C.*

,, *Mya cancellata*, (*Platyodon*), Conr. Dead valves, St. Luis Obispo, *Dr. Antisell.*

,, *Sphænia Californica*, (*Cryptomya*), Conr. San Francisco, *Trask.*

386. *Mytilimeria Nuttalli*, Conr. A group, nestling in a white, friable, arenaceous substance, was obtained at San Diego by *Lieut. Trowbridge.*

,, *Pholas* [*Pholadidea*] *penita*, Conr., =*P. concamerata*, Desh. From worn rock which drifted into Shoalwater Bay, attached to the roots of *Macrocystis*, the giant seaweed, *Cooper*; De Fuca, *Suckley*; mouth of Umpqua River, Oregon, *Dr. Vollum.*

The above list must be considered as a *résumé*, not merely of the shells of the N. P. Railroad Survey, but also of all those examined by Judge Cooper, from the Smithsonian Museum and from his own private collection. It is peculiarly valuable as preserving the notes concerning station, &c., of the original explorers, and has therefore required a more lengthened analysis.

The land-shells collected by Dr. Newberry in the Pacific Railroad Survey were described by W. G. Binney, Esq., with his accustomed accuracy. His paper will be found in the Reports, vol. vi. pp. 111–114. The following are the only species enumerated:—

1. *Helix fidelis*, Gray, Chem., Pfr., Rve.,=*H. Nuttalliana*, Lea, Binney, sen., De Kay. Portland, Oregon, *Newberry*. Local.
2. *Helix infumata*, Gld., Proc. Bost. N. H. S., Feb. 1855, p. 127. Hills near San Francisco, *Newberry*. Extremely rare.
3. *Helix æruginosa*, Gld., var. *β. loc. cit.* North of San Francisco, *Newberry*. Rare.
4. *Helix Dupetithouarsi*, jun., Desh., Chem., Pfr., Rve.,=*H. Oregonensis*, Lea, Pfr. San Francisco, Benicia, Cal.; Klamath Lake, Oregon; *Newberry*. "One of the commonest and most widely distributed species of the Pacific region."

102. The U. S. Government also sent out a "North-west Boundary Commission," in charge of Archibald Campbell, Esq. The natural-history arrangements were superintended by the Smithsonian Inst., and Dr. C. B. R. Kennerley was appointed naturalist to the Expedition. At his request, I undertook to prepare a Report of the Mollusca, to be published and illustrated in a form corresponding to the Pacific Railroad Reports; Dr. Alcock kindly undertaking to dissect the animals, and Mr. Busk to examine the Polyzoa. Dr. Kennerley died on his return from a three years' exploration; and the civil war has thus far delayed any further publication. The materials have, however, been thoroughly investigated. They consist principally of dredgings in Puget Sound. On reference to the maps published by the U. S. Coast Survey, it will be seen that this inland sea consists of a remarkable labyrinth of waters, fiord within fiord, and only indirectly connected with the currents of the Pacific Ocean. It might therefore be expected to furnish us with the species of quiet migration, and perhaps with those still living from a period of previous altered conditions. No doubt it will furnish new materials to reward the labours of many successive naturalists. The pre-

maturely closed investigations of Dr. Kennerley are only the beginning of a rich harvest. Dr. George Suckley, late assistant-surgeon of the U. S. army, was appointed to complete the natural-history work, after his lamented death. A complete list of the species collected will be found in the fifth column of the Vancouver and Californian table, *v. infrà*, par. 112. The particulars of station, &c., and all the knowledge which the laborious explorer had collected, are lost to science. It is quite possible that some of the species here accredited to Puget Sound were obtained in neighbouring localities in the Straits of De Fuca. The specimens are in beautifully fresh condition, and of most of them the animals were preserved in alcohol. The following are the shells first brought from the Vancouver district by the American N. W. Boundary Commission, the diagnoses of new species being (according to custom) first published in the Proceedings of the Ac. Nat. Sc. Philadelphia.

No.
1. *Zirphæa crispata.* Two living specimens of this very characteristic Atlantic sp.
2. *Saxicava pholadis.* Several living specimens.
3. *Sphænia ovoidea*, n. s. One sp. living.
4. *Cryptomya Californica.* Several living sp.
5. *Thracia curta.* One specimen.
6. *Mytilimeria Nuttallii.* Three sp. living at base of test of Ascidian. [The animal appeared too peculiar to venture on a dissection. It has been entrusted to Dr. Alcock, of the Manchester Museum.]
7. *Neæra pectinata*, n. s. One sp. living.
8. *Kennerlia filosa*, n. s. and n. subg. Several living specimens.
9. *Psammobia rubroradiata.* One fresh specimen of uniform tint.
10. *Macoma* (? v.) *expansa.* Adult broken; young living. Belongs to a group of forms classed together by some writers under *lata* or *proxima*, but the characters of the hinge and mantle-bend have not yet been sufficiently studied.
11. *Macoma yoldiformis*, n. s. One valve.
12. *Angulus modestus*, n. s., but closely allied to the eastern *A. tener*, Say. Two sp. living.

12*b*. *Angulus* (? *modestus*, var.) *obtusus.* Several fresh specimens.

13. *Clementia subdiaphana*, n. s. Very rare, living. Intermediate between *Clementia* proper and the *prora* group of thin *Callistæ.*
14. *Psephis Lordi*, Baird. Several living sp. from which the subg. was eliminated.
15. *Venus Kennerlyi*, Rve. Very rare. One sp. living. Some of the shells called *V. astartoides* by Midd. may be the young of this.
16. *Petricola carditoides.* Several fresh specimens.
17. *Astarte* (? var.) *compacta.* One sp. living; may hereafter be connected with *A. compressa.*
18. *Serripes Grœnlandicus.* Several young living specimens.
19. *Lucina tenuisculpta*, n. s. Two living specimens, of which one had the surface disintegrated.
20. *Cryptodon serricatus*, n. s. One living sp.
21. *Kellia Laperousii.* A few living specimens.
22. *Kellia suborbicularis.* A few living specimens.
23. *Lasea rubra.* One sp. living.
24. *Pythina rugifera*, n. s. Two living sp. Intermediate between *Pythina* and *Kellia.*
25. *Tellimya tumida*, n. s. One sp. living.
26. *Modiolaria lævigata.* Two living sp.
27. *Modiolaria marmorata.* One sp. living. (A shell in the U. S. E. E. Col., though marked "Fiji" in Dr. Gould's MS. list, probably came from Puget Sound, being thus confirmed.)
28. *Nucula tenuis.* Two sp. living*.
29. *Acila castrensis.* One sp. living.
30. *Leda fossa*, Baird. One normal sp. living.

* These species were kindly determined by Mr. Hanley.

No.
31. *Leda minuta*, Linn. One sp. living*.
32. *Yoldia lanceolata*, J. Sby. Two sp. living*.
33. *Yoldia amygdala*. One sp. living*.
34. *Haminea hydatis*. Two sp. living.
35, 36. Two species of Tectibranchiates, not yet worked-out by Dr. Alcock.
37. *Tornatina eximia*, Baird. Abundant, living.
38. *Cylichna* (?var.) *attonsa*. One living sp. Probably a variety of *cylindracea*.
39. *Dentalium rectius*, n. s. Very rare, dead.
40. *Acanthopleura scabra*. One young living sp.
41. *Mopalia Grayii*, n. s. One living sp.
42. *Mopalia Hindsii*. One living sp.
43. *Mopalia sinuata*, n. s. Two sp. living. } A well-marked group in the genus.
44. *Mopalia imporcata*, n. s. Two sp. living. }
45. *Ischnochiton* (*Trachydermon*) *trifidus*, n. s. One living sp.
46. *Ischnochiton* (*Trachydermon*) *flectens*, n. s. One living sp.
47. *Ischnochiton* (*Trachydermon*) *retiporosus*, n. s. One living sp.
48. *Ischnochiton* (*Lepidopleurus*) *Mertensii*. Rare, living.
49. *Lepeta cæcoides*, n. s. Three sp. living.
50. *Calliostoma variegatum*, n. s. One living sp.
51. *Margarita* ? *Vahlii*. Three sp. living, = *M. pusilla*, Jeffr., teste A. Ad.
51*b*. *Margarita* (? v.) *tenuisculpta*. Perhaps a var. of *Vahlii*, but sculptured. Several living specimens.
52. *Margarita lirulata*, n. s. Several living specimens, forming a Darwinian group, of which var. α. *subelevata*, var. β. *obsoleta*, and ?var. γ. *conica* might pass for species from single specimens.
53. *Margarita inflata*, n. s. Two sp. living.
54. *Mesalia lacteola*, ?n. s. Two sp. living, but eroded. May prove a var. of *lactea*, but with different sculpture.
54*b*. *Mesalia* (?*lacteola*, var.) *subplanata*. Two sp. living, but eroded.
55. *Lacuna vincta*. One fresh specimen.
56. *Rissoa compacta*, n. s. Not uncommon, living.
57. *Drillia incisa*, n. s. Two fresh specimens.
58. *Drillia cancellata*, n. s. One adolescent specimen.
59. *Mangelia levidensis*, n. s. One fresh specimen.
60. *Mangelia angulata*†. One fresh specimen.
61. *Bela excurvata*, n. s. (Like *Trevelyana*.) One fresh specimen.
62. *Chemnitzia* (? v.) *aurantia*†. One fresh specimen.
63. *Chemnitzia torquata*†. Two fresh specimens.
64. *Chemnitzia tridentata*†. Two fresh specimens.
65. *Eulima micans*, n. s. One fresh specimen.
66. *Velutina lævigata*. Several fine living specimens.
67. *Ocinebra interfossa*. Rare, dead.
68. *Nitidella Gouldii*†. Two living specimens, proving the genus.
69. *Trophon multicostatus*. Two fresh specimens.
70. *Chrysodomus* ?*tabulatus*, jun. One young sp.
71. *Chrysodomus rectirostris*, n. s. One living sp.
72, 73. Two species of Cephalopods, not yet affiliated.

Besides adding more than 70 marine species to the Vancouver branch of the Californian fauna, from specimens in good condition, without a single ballast or exotic admixture, the confirmation of many species, which before rested only on the uncertain testimony of the U. S. E. E. labels, and the affiliation of others which, on the same testimony, had been wrongly assigned to distant and erroneous localities, was no slight benefit to science. The land and freshwater species of the Expedition will be found tabulated, with others, in the separate lists; par. 115.

103. While the American naturalists were thus actively engaged in ex-

† These species were first found by Col. Jewett at Sta. Barbara. *Vide* p. 537.

ploring the regions south of the political boundary, similar explorations, on a less extensive scale, were being made under the direction of the British Government. The naturalist to the British North American Boundary Commission, during the years 1858–1862, was J. K. Lord, Esq., F.Z.S. He made a very valuable collection of shells in Vancouver Island and British Columbia, the first series of which was presented to the British Museum. The new species were described by W. Baird*, Esq., M.D., F.L.S., in a paper communicated to the Zool. Soc., and published in its 'Proceedings,' Feb. 10th, 1863, pp. 66–70.—Another series of shells, from the same district, was presented to the Brit. Mus. by the Lords of the Admiralty, collected by Dr. Lyall, of H. M. Ship 'Plumper.' Two new species from this collection were described by Dr. Baird, in a separate paper, P. Z. S., Feb. 10th, 1863, p. 71. The new species from Mr. Lord's collections have been drawn on stone by Sowerby. The figure-numbers here quoted correspond with the proof-copy kindly furnished by Dr. Baird.—A third series was collected by Dr. Forbes, R.N., in the same Expedition. After Mr. Cuming had made his own selections, this passed into the ordinary London market. It contained several species of peculiar interest. The following are the (supposed) new species of the Survey:—

P.Z.S: Page:	No.	Plate I: Fig.	
66	1	1.	*Chrysodomus tabulatus*, Baird. One broken specimen, Esquimalt Harb., Vancouver Island, *Lord.* [One perfect shell, Neeah Bay, *Swan.*]
..	2	2.	*Vitularia aspera*, Bd. Several living specimens, Esquimalt Harb., Vanc. Island, *Lord.* [Belongs to a group of grooved muricoid Purpurids, intermediate between *Rhizocheilus* and *Cerostoma*, for which the subgenus *Ocinebra* may be reconstituted. These shells are the rough form of *Ocinebra lurida*, Midd.]
67	3	3.	*Chemnitzia Vancouverensis*, Bd. [= *torquata*, Gld.]. Esquimalt Harb., Vanc. Island, *Lord.* From the crop of a pintail Duck. [The artist has failed to represent the peculiar character of the species, which is, that the ribs end above the periphery, so that a smooth belt appears round the spire above the sutures.]
..	4	4.	*Amnicola Hindsii*, Bd. Seven sp., River Kootanie East; nine sp., Wigwam River, west slope of Rocky Mts., 4626 ft. high, Br. Col., *Lord.* Resembles *Paludina* [*Fluminicola*] *seminalis*, Hds.
..	5	5.	*Bullina* (*Tornatina*) *eximia*, Bd. Esquimalt Harb., V. I., *Lord.* Alive in 12 fm.; dead in Duck's stomach. [Not *Bullina*, Add. Gen.]
68	6	6.	*Succinea Hawkinsii*, Bd. Six sp. Lake Osoyoos, Brit. Col., *Lord.*
..	7	7.	*Limnæa Sumassii* †, Bd. Like *L. elodes*, Say. Plentiful. Sumass Prairie, Fraser R., Brit. Col., *Lord.* [Extremely like *L. palustris.*]
..	8	8.	*Physa Lordi*, Bd. Plentiful. Lake Osoyoos, British Columbia, *Lord.* [Larger than *Ph. humerosa*, Gld., and with strong columellar fold.]
69	9	9.	*Ancylus Kootaniensis*, Bd. Six sp., River Kootanie East; five sp., River Spokane, British Columbia, *Lord.*

* It is due to the memory of Dr. Kennerley, as well as to the other naturalists connected with the various American surveys, and the officers of the Smiths. Inst., who so generously entrusted to the writer their unique specimens for comparison with the London museums, to state, that (with two exceptions) the new marine species of the British Survey would have been published long before the appearance of Dr. Baird's paper, but for the derangement of the U. S. natural-history publications, consequent on the slaveholders' secession movement. Although the Smithsonian Inst. had offered to present to the Brit. Mus. their first series of duplicate specimens from these expeditions, which was exhibited at the Manchester Meeting of the Brit. Assoc., where this Report was called-for, no notice was given to the writer of the valuable results of the British survey; and it was only through the private kindness of Drs. Sclater and Baird that he was prevented from adding to the list of synonyms, already, alas! so numerous and perplexing.

† These species are named after places, not after persons, as would be supposed by the terminations.

P.Z.S. Page.	Plate II. No.	Fig.	
69	10	10.	*Chione Lordi*, Bd. From a Duck's stomach. Plentiful. Esquimalt Harb., V. I., *Lord.*
..	11	11.	*Sphærium* (*Cyclas*) *tumidum*, Bd. Plentiful. Sumass Prairie, Fraser River, British Columbia, *Lord.*
..	12	12, 13.	*Sphærium* (*Cyclas*) *Spokani*†, Bd. Two sp., River Spokane; two young sp., Kootanie River, British Columbia, *Lord.* [Closely related to *tumidum*, but more delicate.]
70	13	14.	*Lyonsia saxicola*, Bd. Holes in rocks in Esquimalt Harb., V. I., *Lord.* Japan, teste *A. Ad.* Closely resembles *L. navicula*, Ad. and Rve. [Abundant, and very variable in outline, sometimes like *Saxicava pholadis*, sometimes like *Mytilimeria.* Neeah Bay, *Swan.*]
..	14	15.	*Crassatella Esquimalti*†, Bd. One sp. Esquimalt Harb., V. I., *Lord.* [A true *Astarte*, with external ligament, with one ant. lat. tooth in one valve, and one post. lat. tooth in the opposite, well developed. This character was noticed by J. Sby. in constituting the genus, but becomes obsolete in the typical species. The same peculiarity of margin is seen in *Crassatella.* The external rugæ are singularly irregular, and not always continuous.]
71	15		*Leda fossa*, Bd. 10–15 fm.; one sp. Esquimalt Harb., V. I., *Lyall.* [= *L. foveata*, Baird, MS., on tablet.]
71	16		*Nucula Lyallii*, Bd. 8–10 fm.; one sp. Esquimalt Harb., V. I., *Lyall.* Resembles *N. divaricata*, Hds., *N. castrensis*, Hds., *N. mirabilis*, Ad. and Rve., and especially *N. Cobboldiæ* from the Crag. [In the early stage, the sculpture has several angles, afterwards only one. Both Dr. Kennerley's and Dr. Lyall's specimens appear to be = *Acila castrensis*, Hds.]

The Vancouver Collections having been deposited in separate drawers, except the series mounted for the table-cases, permission has been given (with the kind assistance of Dr. Baird) to examine them minutely, and prepare a revised list of the species. The marine shells will be found in the sixth column of the general Vancouver and Californian Table. The following require special mention.

No.

17. "*Teredo fimbriata*," teste Jeffr.; out of block of wood from Nai-ni-mo Harb., V. I., *Lord.*
 Teredo. Shelly tube of large sp. Esquimalt Harb., *Lord.*
18. *Netastoma Darwinii.* Esquimalt Harb., *Lord.* One adult but injured specimen. [For this singular Pholad, with duck-bill prolongations of the valves, a subgenus of *Pholadidea* is proposed, as its characters do not accord with *Jouanettia*, under which it is placed in the Cumingian Collection.]
19. "*Saxicava rugosa.*" Several typical specimens; Esquimalt Harb., *Lord*, taken out of interior of hard stone, into which they appear to have bored.
20. "*Callista ?pannosa.*" Esquimalt Harb., *Lord.* One young sp. [= *Saxidomus squalidus*, jun.]
21. "*Tapes rigida.*" Esquimalt Harb., *Lord*, common. [An instructive series, some with very close and fine, others with distant, strong ribs. Some have ribs large and rounded, approaching the sculpture of *Cardia.* Some change suddenly from one form to another. = *T. staminea*, var. *Petitii.*]
22. "*Cardium Californiense*, Desh." 8–15 fm. Vancouver Is., *Lyall.* [= var. *blandum.* Tablet contains also young sp. of *C. corbis.*]
23. "*Cardita ventricosa*, Gld." 8–15 fm. Vanc. Is., *Lyall.* [Not ventricose; exactly resembles the East Coast specimens of *Ven. borealis* dredged by Dr. Stimpson.]
24. "*Anodonta cognata*, Gld." [= *A. Oregonensis*, Lea.] Lake Osoyoos, Br. Col., *Lord.* Two sp. Also Freshwater Lake, Nootka Sound, *Lyall.*
 ,, *Anodonta ?Oregonensis*, jun. Freshwater Lake, Nootka, V. I., *Lord*; one sp.
25. *Anodonta ?Nuttalliana.* Freshwater Lake, Nootka, Vanc. Is., *Lord*; one sp.
26. *Anodonta Wahlamatensis.* Freshwater Lake, Nootka, Vanc. Is., *Lord*; four sp.

No.
26. *Anodonta ? Wahlamatensis*, jun. Sumass Prairie, Fraser River, Brit. Col., *Lord*; one specimen.
27. *Anodonta angulata.* Fort Colville, Columbia R., *Lord*; one specimen [irregular and much eroded. The hinge-line is waved and a false "tooth" produced, in consequence of which it has been named] "*Alasmodon.*"
28. "*Pecten rubidus*, Hds." Vanc. Is., *Lyall.* [Hinds's type in Br. Mus. appears the ordinary form, of which *P. hastatus*=*hericeus* is the highly sculptured var. This shell, which is more allied to *Islandicus*, may stand as *P. Hindsii.*]
29. *Hinnites giganteus.* Island 3 miles above Cape Mudge, *Lyall.*
30. *Ostrea lurida.* Esquimalt Harb., *Lord.* Dredged-up by Indians in small hand-nets with long handles, in 2–3 fm., on mud-flats.
31. "*Placunanomia cepio*, Gray." Esquimalt Harb., *Lord.* On island rock, between tide-marks. [=*P. macroschisma*, smooth, hollow form.]
32. "*Chiton* (*Platysemus*) *Wossnessenskii*, Midd.,=*C. Hindsii*, Rve." Esquimalt Harb., *Lord.* One very fine specimen. [Quite distinct from *Mopalia Hindsii* (Gray); differs but slightly from *M. muscosa*, Gld.]
33. "*Chiton ? lævigatus.*" Esquimalt Harb., *Lord.* One specimen. [=*Ischnochiton flectens.*]
34. "*Chiton dentiens*, Gld., ?=*marginatus.*" Esquimalt Harb., *Lord.* Two specimens. [=*Ischnochiton pseudodentiens.* Not congeneric with the British *Leptochiton cinereus*=*marginatus.*]
35. *Acmæa* "*mitella*, Mke." Esquimalt Harb., *Lord.* [Probably *A. pelta*, jun. Not sculptured, as is the tropical species.]
36. "*Acmæa ? testudinalis*, jun." Esquimalt Harb., *Lord.* One young sp. [with extremely close fine striæ; colour in festoons of orange-brown pencilling on white ground. Might stand well for *A. testudinalis*, but probably=*A. patina*, var. *pintadina.*]
37. *Margarita* "*costellata*, Sby." Esquimalt Harb., *Lord.* [=*M. pupilla*, Gld.]
38. *Crepidula lingulata*, Gld. Esquimalt Harb., *Lord.* Three young sp. [Apex smooth, imbedded, passing into the *aculeata* type. The species probably= *C. dorsata*, Brod.]
39. "*Melania silicula*, Gld., ?=*rudens*, Rve." Attached to weeds and floating sticks in swift stream on prairie, at Nisqually, W. T., *Lord.* [=*plicifera*, small var.]
40. *Priene Oregonensis.* Port Neville, 6 fm., *Lyall.* [Very fine; but opercula probably misplaced.]
41. "*Nitidella*" *gausapata*, Gld. Esquimalt Harb., *Lord.* [A beautiful series of highly painted specimens. Operculum Nassoid, not Purpuroid; therefore ranks under *Amycla.*]
42. "*Vitularia lactuca.*" Vancouver's Island, *Lyall.* [A fine series of *Purpura crispata* and vars., among which is a lilac-tinted specimen.]
43. *Purpura decemcostata*, Vanc. Is., *Lyall.* [=*canaliculata.* Operc. as in *Ocinebra lurida.*]
44. "*Fusus Orpheus*" [Bd., not] Gld. Esquimalt Harb., *Lord.* Five sp., with crabs. [=*Ocinebra interfossa*, very fine.]
45. *Trophon Orpheus*, Gld. Esquimalt Harb., *Lord.* One fresh specimen.
46. *Helix Townsendiana*, very fine. Sumass Prairie, Fraser River, *Lord.*
46*b*. "*Helix Townsendiana*, small var." Fort Colville, Columbia R.; also summit of Rocky Mts., *Lord.*
47. *Helix fidelis*, typical, jun. and adult. Vanc. Is., *Lord.*
47*b*. *Helix fidelis.* Large but very pale var. Sumass Prairie, Fraser R., *Lord.*
48. "*Helix Thouarsii*, jun." Sumass Prairie, Fraser R., *Lord.*
49. "*Helix labiata*=*Columbiana*, var." Vancouver Is., Lord, [closely resembling *H. rufescens*].
50. "*Helix vellicata*, Fbs." Sumass Prairie, Fraser R., *Lord.* [=*Vancouverensis.*]
51. *Helix* [like *rotundata*]. Fort Colville, Columbia R., *Lord.* Two specimens.
52. *Zonites* [like *excavata*]. Fort Colville, Columbia R., *Lord.* One specimen.
53. *Zonites* [like *electrina*]. Fort Colville, Columbia R., *Lord.* Seven specimens.
54. *Pupa*, sp. ind. jun. Lake Osoyoos, British Columbia, *Lord.* One specimen. [Genus not found before, north of California.]

No.
55. "*Succinea rusticana*, Gld." Sumass Prairie, Fraser R., *Lord.* [Scarcely to be distinguished from the European *S. putris.*]
56. "*Planorbis corpulentus*, Say." Lake Osoyoos; Syniakwateen; Marsh, Kootanie East, Brit. Col., *Lord.*
57. *Planorbis ?subcrenatus*, var. Sumass Prairie, Brit. Col., *Lord.*
58. "*Limnæa stagnalis*," typical, fine, and abundant. Lake Osoyoos, Fraser R., *Lord.*
58. *Limnæa stagnalis*, long narrow spire, mouth swollen, closely fenestrated. Marshy stream, Syniakwateen, *Lord.*
59. "*Limnæa ?desidiosa*, Say." Lake Osoyoos; three sp., *Lord.* [Exactly resembles a var. of the widely distributed *L. cataracta*, which was found in profusion in the Madison Lakes, Wisc.]
60. "*Limnæa ?desidiosa*, Say." Syniakwateen, Brit. Col., *Lord.* One sp. [Very turrited, whirls swollen; epidermis finely striated. The same species occurs as "*L. megasoma*, Say. Lake Osoyoos."]
61. "*Physa heterostropha*, Say." Sumass Prairie, Fraser R. A variety from Lake Osoyoos, *Lord.*
62. *Physa* [probably young of *Lordi*, but with orange band inside labrum.] Kootanie R. East, Brit. Col., *Lord.* One sp.

Besides the shells preserved in the National Collection, the following species were also brought by the Expedition:—

63. *Terebratula unguiculus*, n. s. Vanc. Is., *Forbes.* One adult specimen, Mus. Cum. [Extremely interesting as being the only sculptured species known recent. The young shells from California were naturally affiliated to *Terebratella caput-serpentis* by Messrs. Reeve and Hanley; but the adult has the loop similarly incomplete.]
64. *Rhynconella psittacea.* Vanc. Is., *Forbes.* One specimen, Mus. Cum.
65. *Darina declivis*, n. s. Vanc. Is., *Forbes.* One specimen. [The only other species of *Darina* is from the West Coast of S. America.]
66. *Clementia subdiaphana.* Vanc. Is., *Forbes.* One broken sp.
67. *Saxidomus brevisiphonatus*, n. s. This unique shell is marked "Vancouver Island" in Mr. Cuming's Collection, and is believed by him to have formed a part of Dr. Forbes's series. The shape resembles *Callista*, without lunule. The mantle-bend is remarkably small for the genus.
68. *Melania*, n. s., teste Cuming. Vanc. Is., *Forbes.* [Two specimens, with very fine spiral striæ, sent to Philadelphia for identification.]
69. *Mesalia lacteola.* Vanc. Is., *Forbes.* One sp., Mus. Cum.
70. *Pteropoda*, several species, of which two are new, teste Cuming; but they may have been collected on the voyage. *Forbes.*

The collections made on the British Survey are peculiarly valuable to the student in consequence of the great perfection of the specimens. They have generally been obtained alive, and are often the finest known of their kinds. The occurrence, however, of a specimen of the tropical *Orthalicus zebra*, marked "Vancouver's Island," in Mr. Lord's collection*, is a useful lesson. When such reliable data are thus found possessed of adventitious materials, it will not be regarded as a slight on the collections of the most careful naturalists when specimens are regarded as of doubtful geographical accuracy. In Dr. Lyall's collections there also occur specimens of the well-known *Patella Magellanica* and *Trophon Magellanicus*, duly marked "Vancouver's Island," though no doubt collected in the passage round Cape Horn. The naturalists of the American Expl. Expeditions generally travelled across the continent.

104. The latest exploration undertaken for State purposes is also for our present object by far the most important, both as relates to the number of

* Mr. Lord writes, "The fact of my having found this shell, *alive*, on Vancouver Island is beyond question. How it got there I do not pretend to say; it was very possibly brought by some ship."

species authentically collected and the thoroughly competent and accurate manner in which the necessary information is being recorded. It is no longer left to the great nations bordering on the Atlantic to send exploring expeditions to the Pacific. The State of California, only born in 1850, has so rapidly attained maturity that when she was barely ten years old she considered science a necessary part of her political constitution, and organized a "State Geological Survey," under the direction of Prof. Whitney. To this survey Dr. J. G. Cooper (whose collections for the Pacific Railway Explorations have already been reported, *vide* pp. 597–601) was appointed zoologist, and Mr. W. M. Gabb (formerly of Philadelphia) palæontologist. The friendly relations established with both these gentlemen at the Smithsonian Institution not only put them in possession of the special desiderata on the present branch of inquiry, but have resulted in unreserved interchange of facts and opinions, by means of which a large instalment of the malacological results of the Survey can be embodied in this Report. Dr. Cooper has not only explored the whole coast and the neighbouring islands from Monterey to San Diego, but has dredged extensively from shoal-water to 120 fathoms, keeping accurate lists of all acquisitions from each locality. Having an artist's pencil as well as a naturalist's eye, he has drawn the animals from life, and already subjected many of them to dissection. The slaveholders' war has to some extent suspended the operations of the Survey; but it is confidently expected that the State will do justice to herself by issuing, with suitable illustrations, the full results of her officers' labours. The first public notice of the molluscs appears in the Proc. Cal. Ac. N. S., Nov. 3rd, 1862, pp. 202–207. Here Dr. Cooper, speaking of the new species, writes with a modesty which is not always credited to American naturalists by Europeans,—"As they may have been collected either by the N.W. Boundary Survey or at Cape St. Lucas, it has been considered safest, in order to avoid confusion, to send specimens or drawings of them to [the writer], that he may compare them with the above collections, and decide whether they are really new." He gives valid reasons, however, for describing the following soft Mollusca. Unfortunately for French and German naturalists, the diagnoses are in English only.

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202. *Strategus* (n. g.) *inermis*, n. s. More highly organized than any other genus of *Opisthobranchiata*; creeps slowly among the grasses in the muddy parts of San Diego Bay, looking like a large caterpillar. Not uncommon.

203. *Pleurophyllidia Californica*, n. s. Closely resembles *P. lineata* of S. Europe. "From the distance of locality there can, however, be no identity of species." [?] Numerous in Dec., crawling and burrowing on sandy flats in San Diego Bay; none in Jan., after the floods. [Dr. Cooper writes that the body of fresh water was so great in some places as to kill the marine molluscs for a considerable distance beyond the estuaries, and thus materially alter the pre-existent fauna.]

204. *Doris Montereyensis*, n. s., 6–10 fm., adhering to sandstone. Monterey Bay, very rare. Small specimens in San Francisco Bay, *Frick*.

204. *Doris* (*Asteronotus*) *sanguinea*, n. s. Under stones in San Diego Bay; rare.

204. *Doris* (?*Asteronotus*) *alabastrina*, n. s. Under stones in S. Diego Bay. One sp.

204. *Doris* (?*Actinocyclus*) *Sandiegensis*, n. s. Very active among grass on mud-flats near low-water mark, San Diego Bay; common before the flood.

205. *Æolis* (?*Flabellina*) *opalescens*, n. s. Common among grass in San Diego Bay.

205. *Æolis* (?*Phidiana*) *iodinea*, n. s. Among algæ on rocks outside San Diego Bay.

207. *Tritonia Palmeri*, n. s. San Diego, common "in same localities as the *Diphyllidia*. Named after Mr. Edward Palmer, a zealous naturalist, who assisted me while at San Diego."

Dr. Cooper's second paper "On New or Rare Mollusca inhabiting the Coast of California," in the Proc. Cal. Ac. N. S., Aug. 17, 1863, contains (English) descriptions of the following species. He observes that "*Santa Barbara* and *Santa Barbara Island* are very different in the groups of animals inhabiting them, although the island is only thirty-five miles from the mainland. *Catalina Island* is twenty-four miles from the mainland, and the molluscs are very different from both the mainland and the other islands, being the richest locality on our shores."

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57. *Aplysia Californica*, Cp.; for which is constituted a subgenus, *Neaplysia*; 15 inches by 5 *. Three specimens; San Pedro beach, after storm; stomach full of algæ. Fig. 14.
58. *Navarchus*, Cp. Pr. Cal. Ac., Apr. 1863.
,, *Navarchus inermis*, Cp.,= *Strategus i.*, Cp., *anteà*. Catalina Island, 10 fms., in seaweed. 1 specimen.
,, *Doris albopunctata*, Cp. Santa Barbara, 20 fm., rocky bottom. Catalina Island, rocks, l. w.
,, *Doris Montereyensis*, Cp. Santa Barbara Island, rocks, l. w.
,, *Doris sanguinea*, Cp. 4 sp. with the last. "Stellate structure not discovered."
,, *Doris Sandiegensis*, Cp. 2 sp., with the last. "All these species belong to *Doris*, typical."
59. *Triopa Catalinæ* †, Cp. 4 sp., on algæ among rocks, l. w. Catalina Island.
,, *Dendronotus iris*, Cp. Several sp. thrown on beach by storm, Santa Barbara; 1 sp. dredged on seaweed, 28 fm. Very variable in colour. ? = "*Dendronotus*, sp.," Gld., E. E. Moll.
,, *Æolis Barbarensis*, Cp. 1 sp., 16 fm., rocky bottom, Santa Barbara.
60. *Flabellina opalescens*, Cp.,= *Æolis o.*, Cp., *anteà*. With the last: also shore of Santa Barbara Island, rare.
,, *Phidania iodinea*, Cp.,= *Æolis i.*, Cp., *anteà*. Santa Barbara, beach, 1 sp.
,, *Chioræra leonina*, Gld. 1 sp., in 20 fm. Santa Barbara.

Sept. 7th, 1863. Dr. Cooper described a very interesting new genus of Pulmonates, only found at the head of one ravine in Santa Barbara Island, with "myriads of *Helix Kellettii* [= *H. Tryoni*, v. note *, p. 116], and two other species, probably new." Full particulars of its habits are given. It has the mantle of *Limax*, dentition of *Helicidæ*, and shell resembling *Daudebardia* and *Homalonyx* [= *Omalonyx*, D'Orb.].

62, 63. *Binneya notabilis*, Cp. 3 living and 18 dead shells. Fig. 15 (five views).

Jan. 18th, 1864. The remaining land-shells of the Survey were described (with Latin diagnoses) by Dr. Newcomb, in a paper communicated to the Academy by Dr. Cooper. Specimens of many of them will be found in the Cumingian Collection.

116. *Helix Tryoni*, Newc. Santa Barbara and S. Nicholas Islands, abundant; living. "= *H. Kellettii*, Cp., p. 63."
,, *Helix crebristriata*, Newc. San Clemente Island; abundant. "Closely allied to *H. intercisa*, and very variable."
117. *Helix rufocincta*, Newc. Catalina Island, æstivating under stones; rare. S. Diego; 1 dead sp. Outline like *H. Pytyonesica*: umbilicus open or nearly closed.
,, *Helix Gabbii*, Newc. San Clemente Isl. 1 sp., like *H. facta*.
118. *Helix facta*, Newc. Santa Barbara Isl., very common; San Nicholas Isl., rare. Somewhat like *H. Rothi*.
,, *Helix Whitneyi*, Newc. Near Lake Taho, Sierra Nevada, 6100 feet high. 3 sp. under bark, near stream, with *H. Breweri* and *H. chersina*. Resembles *H. striatella*.

* Molluscs, as well as trees, assume giant proportions in California: e. g. *Schizothærus* (with siphons) 16 in., *Amusium* 8 in., *Lunatia* (crawling) 16 in., *Mytilus* 9 in., &c.

† *Vide* note †, p. 604.

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118. *Helix Breweri,* Newc. Near Lake Taho ; 8 sp. (Also 1 sp. from mountains in Northern California, *Prof. Brewer.*) Like *H. arborea.*

" *Helix Duranti,* Newc. Santa Barbara Isl. "Like *Planorbis albus=hirsutus,* Gld."

Dr. Newcomb also identified the following species in the State Collection:—

119. *Helix arrosa,* Gld. Common near mouth of S. Francisco Bay.

" *Helix arrosa,* yellow var. Santa Cruz, *Rowell.*

" *Helix ? Californiensis,* Lea, or *? Nickliniana,* Lea ; var., *Cooper.*

" *Helix Carpenteri,* Newc. Broken dead shell, head of S. Joaquin Valley, *Gabb.*

" *Helix Columbiana,* Lea. Near S. Francisco.

" *Helix chersina,* Say. Very large, near Lake Taho, *Cooper.*

" *Helix Thouarsii,* Desh. Pt. Cypress, Monterey, *Cooper.*

" *Helix exarata,* Pfr. Mt. Diablo, *Brewer* ; Santa Cruz, *Rowell.*

" *Helix fidelis,* Gray. Humboldt Bay and mountains, lat. 42°, *Brewer.* Black var., *Frick.*

" *Helix infumata,* Gld. Near Ballenas Bay, *Rowell.*

" *Helix Kellettii,* Fbs. S. Diego, Catalina Isl., fine var., *Cooper.*

" *Helix loricata,* Gld. Near Oakland, *Newcomb.*

" *Helix Newberryana,* Bin. Temescal Mountains, near Los Angeles, *Brewer.*

" *Helix Nickliniana,* Lea. Common near S. Francisco Bay, *Cooper.*

" *Helix sportella,* Gld. Near S. Francisco Bay, *Cooper.*

" *Helix Mormonum,* Pfr. San Joaquin Valley, *Gabb* ; north to Mt. Shasta, *Brewer.*

" *Helix Traskii,* Newc. Mountains near Santa Barbara, *Brewer.* May be = *H. Thouarsii,* var.

" *Helix tudiculata,* Bin. Near S. Diego and S. Pedro, *Cooper.*

" *Helix Vancouverensis,* Lea. De Fuca, *Gabb* : perhaps extends south to Humboldt Bay.

Unknown to Dr. Cooper, Dr. Palmer sent a valuable consignment of the shells collected by the Survey between San Diego and S. Pedro to the Smithsonian Institution, without acknowledgment of their source. They would have been described and erroneously assigned to his credit, but for the tardy and accidental discovery of their origin. Dr. Cooper obtained permission to send the first series of duplicates, duly numbered, for identification, to the Smithsonian Institution. This invaluable series was lost in the "Golden Gate." The gold was recovered, and much of it stolen ; the far more precious shells remain, unnaturally located, in their native element—a puzzle, perhaps, to palæontologists in some coming age. Other series, though not so complete, have since been received in safety ; and through the liberality of the Californian Survey and of the Smithsonian Institution, as well as through the energy and kindness of Dr. Cooper, they are already being distributed to the Cumingian Collection, the British Museum, the museums at Cambridge, Mass., Philadelphia, Albany, Montreal, &c., as well as to the collections of working naturalists. The stations being now discovered, it is to be hoped that in a few years Californian shells will cease to be objects of great rarity in this country. At the request of Dr. Cooper, in order that he might proceed with other departments of his labours, all the new species which have been seen in England have been described in conjunction with those from other sources. On those which are only known here by the beautiful drawings sent by the collector, it would be unsafe and premature to impose a name. The diagnoses are being published in the Proc. Cal. Ac. N. S., and should be accredited to the zealous zoologist of the Survey, rather than to the mere artist-in-words who endeavours to represent their forms to the reader. It will be understood that the lists now to be presented, though corrected to the date of going to press, are still incomplete; and that the information has been

compiled from Dr. Cooper's letters received at different times, without opportunity for his revision. Should errors, however, have escaped detection, they will, no doubt, be corrected, and omissions supplied, in the forthcoming Reports of the Survey. The species either new to science, or now first found in the Californian branch of the fauna, are as follows:—

No.
1. *Defrancia intricata.* S. Diego, on *Phasianella compta*, &c. Maz. Cat., no. 13.
2. *Terebratula unguiculus.* Monterey to S. Diego: young shells in 6–20 fm.; not rare.
3. *Terebratella ?caurina.* Catalina Is., 80 fm.; living; rare.
4. *Waldheimia Grayi.* Catalina Is., 120 fm.
5. *Zirphæa crispata.* Fragments from S. Diego appear (very unexpectedly) to belong to this northern species.
6. *Corbula luteola*, n.s. S. Pedro—S. Diego; common near shore.
7. *Neæra pectinata.* Santa Barb., Cat. Is., 40–60 fm. (Puget Sd., *Kennerley*).
8. *Kennerlia bicarinata*, n.s. Cat. Is., 40–60 fm.; rare.
9. *Entodesma inflata*, Conr., = *diaphana*, Cpr. Near S. Diego; 1 valve (*Palmer*).
10. *Plectodon scaber*, n.g. and n.s. Cat. Is.; 2 similar valves, 40–60 fm.
11. *Macoma inquinata.* S. Francisco; rare.
12. *Macoma yoldiformis.* S. Diego. (Puget Sound, *Kennerley.*)
13. *Macoma indentata*, n.s. S. Diego.
14. *Angulus variegatus*, n.s. Mont., Cat. Is., 20–60 fm.; rare. (Neeah Bay, *Swan.*)
15. *Arcopagia lamellata.* S. Diego. = Maz. Cat., no. 58.
16. *Œdalia (Cooperella) scintillæformis*, n. subg., n.s. S. Diego. Santa Barbara Is.
17. *Semele rupium.* Catalina Is.; not rare. (Also Galapagos.)
18. *Semele pulchra.* S. Diego. (Also Cape St. Lucas, Acapulco.)
19. *Semele incongrua*, n.s. Catalina Is., 40–60 fm.; common.
20. *Psephis salmonea*, n.s. S. Diego, Cat. Is., 30–40 fm.; rare.
21. *Psephis Lordi.* Cat. Is., 20–40 fm.; common. (Puget Sound, *Kennerley.*)
22. ?*Astarte fluctuata*, n.s. Cat. Is.; 2 similar valves; 40 fm. (Very like the Crag fossil, *A. omaria*, jun.: but Dr. Cooper considers it a *Crassatella.*)
23. *Venericardia borealis.* Cat. Is., 120 fm. The typical, flat New England form. The small swollen var., = *V. ventricosa*, Gld., is also found at Cat. Is., in 30–40 fm.
24. *Miodon prolongatus.* (Neeah Bay, *Swan.*) Identified from tracing only.
25. *Trapezium.* One extremely young sp. = Maz. Cat., no. 120 (not like *T. Duperryi*). S. Diego.
26. *Chama ?spinosa.* S. Diego. (One young valve sent.)
27. *Cardium (?modestum, var.) centifilosum.* Cat. Is., 30–40 fm. [The differences between this and the Eastern Pacific shell are probably only varietal.]
28. *Hemicardium biangulatum.* Cat. Is., living in 10–20 fm. (Also Acapulco, Panama.)
29. *Liocardium elatum.* S. Diego; very large (Maz. Cat., no. 124).
30. *Lucina tenuisculpta.* S. Diego, living in 4 fm. (Also Puget Sound, *Kennerley.*) Var., dead in 120 fm., Cat. Is. (approaching *L. Mazatlanica*, Maz. Cat., no. 144).
31. *Lucina borealis.* Cat. Island, 120 fm. " = *L. acutelirata*, Conr., foss. E. E." [Exactly agrees with British examples.]
32. *Cryptodon flexuosus.* Cat. Is., 120 fm. Ditto.
33. *Kellia suborbicularis.* S. Diego; Cat. Is., 30–40 fm. Ditto.
34. *Kellia* (var.) *Chironii.* S. Diego. (Also Neeah Bay, *Swan.*)
35. *Lasea rubra.* Cat. Is., shore (typical).
36. *Lepton meroëum*, n.s. S. Diego.
37. *Tellimya tumida.* S. Diego. (Also Puget Sound, *Kennerley.*)
38. *Pristes oblongus*, n.g., n.s. S. Diego.
39. *Crenella decussata.* Cat. Is., 10–40 fm.; not rare. (The ordinary British, not the New England form.)
40. *Barbatia gradata.* S. Diego; Maz. Cat., no. 194.
41. *Axinæa intermedia.* Monterey—S. Diego, Cat. Is., 40–60 fm. [Scarcely differs from the South American shell. It is the *A. Barbarensis*, Conr., of Pac. R. R. fossils, teste Cooper.]

No.
42. *Acila castrensis.* Cat. Is., 40–60 fm. (Also Puget Sound, *Kennerley.*)
43. *Leda cuneata,* teste Hanl. Mont.—S. Diego; Cat. Is., 10-60 fm.
44. *Leda hamata,* n.s. Santa Barbara; Cat. Is., 20–60 fm.; common.
45. *Verticordia ornata,* D'Orb. Santa Barbara; Cat. Is., 20–40 fm. [Exactly accords with the Japanese species, *novemcostata,* teste A. Adams.]
46. *Bryophila setosa.* (Cape St. Lucas, *Xantus.*) Identified from tracing, no. 980.
47. *Lima orientalis* (in Mus. Cum.,=*dehiscens,* Conr., teste Cooper). Mont.—San Diego; Cat. Is., beach to 20 fm.; common.
48. *Limatula subauriculata.* 40–120 fm., Cat. Is.; not rare: 1 valve in 4 fm., San Diego. [Exactly agrees with British specimens.]
49. *Janira dentata.* Monterey, S. Diego, beach to 20 fm. (Also Cape St. Lucas, *Xantus.*)
50. *Cavolina telemus.* Cat. Is.; dead in 30-60 fm. (Also Vancouver, *Lyall.*)
51. *Tornatina carinata.* S. Diego. (Also Mazatlan, *Reigen.*)
52. *Pedipes liratus.* S. Diego. (Also Cape St. Lucas, *Xantus.*)
53. *Dentalium* (var.) *Indianorum.* Mont.—Cat. Is., 20 fm.; common. [Probably a striated var. of *pretiosum,* which Sowerby doubtfully, and Dr. Baird confidently, affiliate to *D. entale.*]
54. *Dentalium semipolitum.* S. Diego. (Also La Paz.)
55. *Dentalium hexagonum.* S. Diego. (Also W. Mexico.)
56. *Acanthochites avicula,* n.s. Cat. Is., 8–20 fm.; rare.
57. *Acanthopleura fluxa,* n.s. Cat. Is.
58. *Ischnochiton veredentiens,* n.s. Cat. Is., 10–20 fm.
59. *Ischnochiton* (*Lepidopleurus*) *pectinatus,* n.s. Cat. Is., beach.
60. *Ischnochiton* (*Lepidopleurus*) *scabricostatus,* n.s. Cat. Is., 8–20 fm.
61. *Ischnochiton* (*Trachydermon*) *pseudodentiens.* S. Diego. (Also Puget Sound, *Kennerley.*)
62. *Ischnochiton* (*Trachydermon*) *gothicus,* n.s. Cat. Is., 8–20 fm.
63. *Leptochiton nexus,* n.s. Cat. Is., 20–80 fm.
64. *Nacella* (?*paleacea,* var.) *triangularis.* Monterey.
65. ?*Nacella subspiralis.* Cat. Is., 10–20 fm. [May be the young of the long-lost *Patella calyptra,* Mart.; unless that be a broken *Crepidula adunca.*]
66. *Scurria* (? var.) *funiculata.* Monterey; rare.
67. *Puncturella cucullata.* Monterey. (Also Puget Sound, U. S. E. E.)
68. *Puncturella Cooperi,* n.s. Cat. Is., 30–120 fm.; not rare.
69. ?*Imperator serratus,* ??n.s. Monterey; Cat. Is., 10–20 fm. [Dr. Cooper thinks this shell probably the young of *Pomaulax.*]
70. ?*Leptonyx bacula,* n.s. Cat. Is., beach, dead.
71. *Gibbula optabilis,* n.s. S. Diego.
72. *Calliostoma supragranosum,* n.s. S. Diego.
73. *Calliostoma gemmulatum,* n.s. S. Diego.
74. *Calliostoma splendens,* n.s. Mont.; Cat. Is., 6–40 fm.
75. *Margarita* (?var.) *salmonea.* Mont.; Cat. Is., 6–40 fm. [Intermediate between *undulata* and *pupilla.*]
76. *Margarita acuticostata.* Mont.; Cat. Is., 8–20 fm. [Fossil, Santa Barbara, *Jewett.*]
77. *Solariella peramabilis,* ?n.s. Cat. Is., 40–120 fm.; living. [Differs but slightly from *S. aspecta,* Japan, *A. Ad.*]
78. *Ethalia supravallata,* n.s., and ?var. *invallata.* S. Diego.
79. *Liotia fenestrata,* n.s. Cat. Is., beach to 40 fm.; dead.
80. *Liotia acuticostata,* n.s. Mont.; Cat. Is., 10–20 fm.
81. *Crepidula excavata,* var. jun. Santa Barbara Island.
82. *Galerus contortus,* n.s. Mont.—S. Diego, 20-40 fm.
83. *Hipponyx serratus.* Santa Barbara Island; 1 sp. Maz. Cat., no. 346.
84. *Cæcum crebricinctum,* n.s. Mont.—S. Diego; Cat. Is., 8–20 fm.
85. *Cæcum Cooperi,* n.s. S. Diego. [Two fine species of the *Anellum* group.]
86. *Turritella Cooperi,* ?n.s. S. Diego; Cat. Is.; common. [May prove identical with one of Conrad's imperfectly described fossils in P. R. E. E.]
87. *Mesalia tenuisculpta,* n.s. S. Diego; shoal water.

No.
88. *Bittium armillatum.* S. Diego. [Fossil, Santa Barbara, *Jewett.*]
89. *Bittium asperum.* S. Diego; Cat. Is., beach to 40 fm. [Fossil, Santa Barbara, *Jewett.*]
90. *Isapis fenestrata*, n.s. S. Diego. (Also Neeah Bay, *Swan.*)
91. *Isapis obtusa*, n.s. Mont.—S. Diego; Cat. Is., 10–20 fm.
92. *Rissoina interfossa*, n.s. Mont.; Cat. Is., 8–10 fm.
93. *Rissoa acutelirata*, n.s. S. Diego *.
94. *Fenella pupoidea*, n.s. Mont., 20 fm.; rare.
95. ?*Amphithalamus lacunatus*, n.s. S. Diego. 1 immature specimen.
96. *Diala acuta*, n.s. Mont.; Cat. Is., beach to 10 fm.
97. *Diala marmorea*, n.s. Monterey, S. Diego; very rare.
98. *Styliferina turrita*, n.s. S. Diego.
99. *Jeffreysia translucens*, n.s. S. Diego.
100. *Cythna albida*, n.s. S. Diego.
101. *Trivia Solandri.* Santa Barbara and St. Nicholas Is.; common.
102. *Obeliscus ?variegatus.* S. Diego. (Also La Paz, Cape St. Lucas.)
103. *Chrysallida pumila*, n.s. S. Diego; Cat. Is.
104. *Chrysallida cincta*, n.s. Sta. Barbara Is.; very rare.
105. *Chemnitzia chocolata*, n.s. S. Diego.
106. *Chemnitzia* (?*tenuicula*, var.) *subcuspidata.* S. Diego.
107. *Eulima micans*, n.s. S. Diego. Cat. Is., 30–40 fm. (Also Puget Sound, *Kennerley.*)
108. *Eulima compacta*, ?n.s. S. Diego. } Dr. Cooper has not decided whether
109. *Eulima rutila*, ?n.s. Monterey. } these be distinct species.
110. *Scalaria bellastriata*, n.s. Monterey.
111. *Scalaria subcoronata*, n.s. Monterey.
112. *Scalaria crebricostata*, n.s. Monterey, S. Diego.
113. *Scalaria ?Cumingii.* S. Diego.
114. *Scalaria ?Indianorum*, var. S. Diego. [Probably conspecific with the Vancouver shells.]
115. *Opalia borealis.* Farallones Is. (Also Neeah Bay, *Swan.*)
116. *Opalia spongiosa*, n.s. Monterey.
117. *Opalia retiporosa*, n.s. Cat. Is., rare and dead in 40 fm.
118. *Cerithiopsis columna*, n.s. Monterey.
119. *Cerithiopsis assimilata.* Cat. Is. = Maz. Cat., no. 563.
120. *Triforis ?adversa.* Cat. Is., 10–40 fm., very rare. [The specimens sent cannot be distinguished from the Herm shells.]
121. *Priene Oregonensis.* "Comes south to Monterey."
122. *Nassa insculpta*, n.s. Cat. Is., living in 40 fm., rare.
123. *Amycla undata*, n.s. Cat. Is., not rare in 40 fm.
124. *Amycla chrysalloidea*, n.s. S. Diego, shoal water.
125. *Anachis subturrita*, n.s. S. Diego.
126. *Trophon triangulatus*, ?n.s. Cat. Is., 60 fm. [Resembles the young of *Murex centrifugus.*]
127. *Argonauta argo.* "Hundreds on beach at Sta. Cruz Is."
128. *Octopus punctatus*, Gabb. San Clemente Is.
129. *Onychoteuthis fusiformis*, Gabb. San Clemente Is.
130. *Ommastrephes giganteus*, D'Orb. San Clemente Is.
131. *Ommastrephes Ayresii*, Gabb. San Clemente Is. "Hundreds on the beach."

Besides the above, several species are now satisfactorily assigned to the fauna, the evidence for which was before considered doubtful. Such are—

132. *Waldheimia Californica*, Koch [non auct., = *globosa*, Patagonia]. 120 fm. Catalina Is.
133. *Clidiophora punctata.* S. Diego to Sta. Cruz; valves common, but rare living.
134, 135. *Standella Californica, planulata*, et ?*nasuta.* Conrad's types being lost, and his species imperfectly described from very young specimens, a difficulty

* Most of the minute shells from S. Diego, quoted without station, were found in the shell-washings of the consignments from Dr. Cooper and Dr. Palmer.

No.

attends their identification. Dr. Cooper found very large valves (resembling *Schizothærus*) in abundance, but much deformed by the entrance of sand, and apparently killed by the fresh waters of the great flood. The large shells belong to two very distinct species, which are probably those of Conrad; among the small shells is perhaps a third, which may be Dr. Gould's suppressed *nasuta*.

136. *Raëta undulata.* This remarkable reverse of the Atlantic *R. canaliculata* is also confirmed by rare valves from the S. Diegan district. It is not congeneric with *Harvella elegans,* to which it bears but a slight external resemblance.

137. *Tapes tenerrima.* Large dead valves of this very distinct species were found with the *Standellæ,* and confirm Col. Jewett's young shells described as from Panama.

138. *Pecten paucicostatus.* Sta. Barbara Is. [Described from Col. Jewett's valves.]

139. *Bulla Quoyii.* S. Diego. Maz. Cat. no. 226.

140. *Truncatella Californica.* S. Diego.

141. *Acmæa rosacea.* Monterey to S. Diego. This shell is named *pileolus,* Midd., in Mus. Cuming, but does not agree with the diagnosis. It can hardly be distinguished from Herm specimens of *A. virginea.* It was first brought by Col. Jewett, but referred to Panama.

142. *Amphithalamus inclusus.* S. Diego. [Several specimens of this minute but remarkable new genus confirm a solitary shell in Col. Jewett's mixed collections.]

143. *Myurella simplex.* Very variable in sculpture, as befits the species which forms the northern limit of a group common between the tropics. Col. Jewett's shell was in poor condition, and supposed to be the young of a Gulf species.

144. *Volvarina varia.* S. Diego, Cat. Is. [Sta. Barbara, *Jewett*; also C. S. Lucas.]

145. *Nassa Cooperi,* Fbs. S. Diego, Cat. Is. [This Kellettian shell has a double right to its name, now that Dr. Cooper has ascertained its habitat.]

The information on station, &c., which Dr. Cooper has sent with regard to previously known species, will be found incorporated in the general table of the fauna. The following notes, extracted from his letters, are too valuable to be omitted :—

Haliotis Californiensis. "This form is so rare that I think it only a var. of *Cracherodii.*"

Haliotis. Several specimens from the Farallones present characters intermediate between *corrugata, rufescens,* and *Kamtschatkana.* It is not yet ascertained whether they are hybrids or a distinct species.

"*Livona picoides* I have not found, though I have seen fresh ones from Pt. Conception."

"?*Serpulorbis squamigerus.* Common south of Pt. Conception; has no operculum." [The young begins like *V. anellum,* Mörch.]

Macron lividus. Point Loma, S. Pedro, common; extends northwards to the Farallones. [=*Planaxis nigritella,* Newcomb, MS.; non auct.]

"*Olivella semistriata,* Gray, fide Newc., is a species found N. of Monterey only." [As Dr. Gray's species is from Panama, that of Newcomb is probably *O. bœtica.*]

"*Nassa interstriata,* Conr., foss. (?=*N. paupera,* Gld.); resembles *N. fossata,* Gld. (=*B. elegans,* Rve.*), but distinct. Common south from Sta. Barbara." [Probably =*N. perpinguis,* Hds. *N. paupera* is quite distinct,=*N. striata,* C. B. Ad., teste Cuming.]

"*Fissurella violacea* I have seen from Catalina Is." [Esch.'s shell is generally considered S. American. ? May Dr. Cooper's be a form of *volcano.*]

Acmææ. With regard to limpets and other variable shells, Dr. C. writes:— "From my examination of large numbers of specimens, I am more and more compelled to believe that hybrids are very frequent between allied

* *Nassa elegans* was first published, by J. Sowerby, in the Min. Conch. 1824.

species, and that the comparatively few links that are met-with in large series of two forms should not be allowed to unite them, but be considered as hybrids."

Lunatia Lewisii. Abundant on beach. [One sp. measures $5\frac{3}{4}$ in., and the animal of a much smaller one (4 in.) is 11 inches long.]

Ostrea. "The same species throughout to S. Franc.: S. Diego," *Cooper.* [Besides the typical northern shell, *O. lurida,* are well-marked ?vars. *laticaudata, rufoides,* and *expansa.*]

There are also several species which are quoted in Dr. Cooper's letters, or appear from his sketches to be quite distinct, or at least new to the fauna; but they have not yet been sent for identification. Among these the following are the most important. The MS. numbers refer to the tracings which Dr. Cooper kindly copied from his original drawings. Where a "—" appears, the information is derived from his letters only.

MS. No.
402. Allied to ?*Thracia.*
— *Cyathodonta,* probably *plicata,* Desh. (Cape St. Lucas, *Xantus*).
620*a.* Figure accords exactly with *Venus toreuma,* Gld. Catalina Is., beach.
1058. Figure accords with *Lioconcha hieroglyphica.* Catalina Is., 120 fm.
1060. Resembles *Sunapta.* Catalina Is., 40 fm.
676. Resembles *Crassatella Pacifica.*
874. *Lucina.*
983. *Nucula,* with concentric sculpture. Sta. Barbara, 15 fm.
— *Yoldia.* One fresh valve of a large and remarkable species, 2·6 by 1·2 in., with fine concentric sculpture, very inequilateral: Sta. Cruz; on beach.
751*a.* ?*Ianthina.*
1077, 1078. *Chitonidæ.* Two highly sculptured species. Sta. Barbara, 12 fm.
— ?*Gadinia.* Cat. Is., *Cooper*; Farallone, Is., *Rowell.* "The animal differs in having pectinated flattened tentacles. It may be the type of a new genus *Rowellia.*"
466. *Emarginula.* [The first appearance of the genus on the W. American coast.]
415*a.* *Glyphis.*
354*a.* Like *Haplocochleas.* Sta. Barbara, 15 fm.
564. Like *Pyrgola.* 40 fm.
— *Trivia sanguinea.* Dredged dead in Cat. Is.
— *Trivia.* "Thinner and larger than *sanguinea.* Common in Lower Cal." [?= *Pacifica.*]
— "*Terebra specillata.*" One sp. near S. Pedro.
— *Pleurotomidæ.* Several species are represented only by single specimens. Among them are
588. *Drillia.*
1021. *Drillia,* 2 in. long, shaped like *Mitra.* One worn sp. Catalina Is., 120 fm.
1020. *Drillia,* reversed. Catalina Is., 60 fm., living.
479*a.* *Clathurella* (large). Sta. Barb., 20 fm.
663. *Clathurella,* 15 fm., Sta. Barb.
1852. ?*Clathurella,* 40 fm.
1053. ?*Daphnella,* 60 fm.
419, 426. Two species of shells resembling *Daphnella.*
1055. ?*Bela,* 80 fm.
423*a.* *Mangelia,* 15 fm., Sta. Barb.
397*b.* Shape of *Cithara,* without ribs. Catalina Is., beach.
1028. "?*Aclis,*" reversed. One sp., Cat. Is., 120 fm. [The figure more resembles a young Vermetid.]
463. "*Cancellaria* ?*Tritoniæ,* Sby. Agrees with Dr. Newcomb's specimen." S. Diego, one dead on beach, $2\frac{1}{4}$ in. long.
817. *Cancellaria.* Fragment of a second species equally large.
1038. *Sigaretus.* 40 fm., dead, Cat. Is.
1050. *Lamellaria.* 10 fm., Sta. Barbara.
(385*a,* 464, 818.) *Naticidæ.* 3 sp.

MS. No.

576. Possibly a scaly var. of *Monoceros engonatum*; like the *Purpura*, var. *imbricata*, of Europe, but of different colour and texture; ? = *spiratum*, Blainv.

1001. Figure resembles *Vexilla fuscolineata*, Pse. Sandwich Is.

— "*Nassa*, smooth, with thick lip." Cat. Is., 30 fm. [Comp. *insculpta*.]

— ?*Macron Kellettii*. Cat. Is., dead, in 60 fm.

— *Chrysodomus ?tabulatus*. Cat. Is., 120 fm., young, dead.

— *Fusus*, "like *geniculus*, Conr." Farallones Is.

411. *Trophon*, like *multicostatus*.

515*b*. *Muricidea*. Cat. Is., 40 fm. [The young shells called *Trophon*, *Typhis*, &c., by Dr. Cooper can scarcely be identified without a series, and from tracings only.]

515*d*. ?*Typhis*. Sta. Barb., 15 fm.

520. *Pteronotus centrifugus*, jun. S. Pedro; rare on beach.

384*b*. *Muricidea*, like *alveata*. Mont.—S. Diego.

956. ?*Siphonalia*. Monterey, Sta. Barb., beach.

In Prof. Whitney's Preliminary Report on the Survey, Proc. Cal. Ac. p. 27, May 4th, 1863, he states approximately as the result of Dr. Cooper's malacological labours, up to the close of 1862:—

No. of species in the collection	335
Of which are new to California, and believed to be undescribed	123
Other supposed Californian species not yet collected	65

In a Survey conducted with such care, even negative evidence is of some importance, though not conclusive. Dr. Cooper has not been able to obtain the following species:—

Discina Evansii.
Strigilla carnaria. [Mr. Nuttall's specimens were probably Atlantic.]
Venus dispar.
Trapezium Californicum. [= *Duperryi*, = *Guiniacum*.]
Lucina bella. [Perhaps = *pectinata*, Cpr.; but the type seems lost.]
Modiola nitens. [Probably an error in the Cumingian label.]
Mytilus glomeratus, " = *edulis*, var." [Perhaps an accidental var. from being crowded on a floating stick.]
Barbatia pernoides. [Very probably an error in Dr. Gould's label.]
Arca multicostata. "Must have been brought to S. Diego."
Pecten purpuratus. [Ascribed to the fauna from abundant valves marked "Cal." in the U. S. E. E. collections, but certainly from S. America. Dr. Cooper has unfortunately not been able to discover any of the species described by Hds.]
Radius variabilis. "Doubtless exotic."
Polinices perspicua. "Probably Mexican."
Ranella triquetra. "Probably Mexican." [Guaymas.]

105. Having now presented to the student an analysis of all that is yet known of the results of public surveys, it remains that we tabulate what has been accomplished by private enterprise. Mr. J. Xantus, a Hungarian gentleman in the employ of the United States Coast Survey under the able direction of Professor Bache, was stationed for eighteen months, ending July 1861, at Cape St. Lucas, the southern point of the peninsula of California. It is a source of great benefit to natural science that the Secretary of the Smithsonian Institution is also one of the acting members of the Coast Survey Board; and that a harmony of operations has always existed between the directors of these two scientific agencies in Washington. The publications of the Coast Survey have earned for themselves a reputation not surpassed by those of the oldest and wealthiest maritime nations. For obtaining data on geographical distribution, Cape St. Lucas was a peculiarly valuable station, being situated near the supposed meeting-point of the two faunas (v. B.A.

Rep.p.350); and also, not being a place of trade, or even an inhabited district, likely to be free from human importations, although we should be prepared to find dead exotics thrown on its shores both by northern and by tropical currents. In his solitary and what would otherwise have been monotonous life, Mr. Xantus found full employment in assiduously collecting specimens in all available departments of natural history; having received ample instructions, and the needful apparatus, from the Smithsonian Institution. The bulk of the shells at first received from him were worn beach specimens; but afterwards several species were preserved, with the animals, in alcohol. Mr. Xantus generously presented the first series of the molluscs to the Smithsonian Museum, reserving the second for his native land. The first available duplicates of the shells not occurring in the Reigen collection will be found in the British Museum or in the Cumingian cabinets*. Although the whole series would have found little favour in the eyes of a London dealer or a drawing-room collector, it proved a very interesting commentary on the Reigen and Adams Catalogues: it added about sixty† new forms to the accurately located species of the marine fauna, besides confirming many others, which rested previously on doubtful evidence; and disproved the intermixture of northern species, which, from the map alone, had before been considered probable.

The collection is not only essentially tropical, but contains a larger proportion of Central American and Panama species than are found in the Reigen Catalogue. This may partly be due to the accidents of station, and partly to this projecting southern peninsula striking the equatorial currents. It must also be remembered that the Reigen Catalogue embraces only the Liverpool division of his collection; and that many more species may have existed in that portion of the Havre series which did not find its way to the London markets. Mr. Xantus also obtained individuals of identical species from Margarita Island, and a series containing living specimens of *Purpura planospira* (only thrown up dead on the promontory), from Socorro Island, one of the Revilla-gigedo group. A very few specimens of *Haliotis* and of Pacific shells may have been given to him by sailors or residents: they were not distinguished from his own series in opening the packages. The collection is not yet complete. In consequence of the French occupation of Mexico, it was with difficulty that Mr. Xantus himself "ran the blockade" at Manzanello; and he was compelled to leave there thirty-one boxes of shells, alcoholics, &c., subject to the risks of war.

The Polyzoa were placed in the hands of Mr. G. Busk for examination, and the alcoholics were intrusted to Dr. Alcock, the Curator of the Manchester Natural History Society. Neither of these gentlemen have as yet been

* During the period that Mr. Xantus was out of employment, owing to the derangements of the war, a portion of the duplicates were offered for sale, and will be found in some of the principal collections.

† The editor of a Californian newspaper, kindly forwarded by Mr. Pease, professes to "give entire" a paper read by S. Hubbard at a meeting of the Căl. Acad. N. S. on the collections of Mr. Xantus. The following extract, which is entirely destitute of foundation in fact, is a curious specimen of the tendency to extreme exaggeration, which seems indigenous to some dwellers in a vast country, and has now, it seems, invaded even an Academy of Nat. Sc., who, it is to be hoped for their credit, have not published the paper in their Proceedings:—"The *Mollusca* are represented by over 5000 specimens, not yet considered.—*Shells*: P. P. Carpenter gave, after a hurried survey of the collection, 1700 species last year; but since then the collection has more than doubled. About half of the whole is pronounced by P. P. C. and Isaac Lea to be new." Dr. Lea did not see the collection, as it contained neither Unionids nor Melaniads. Of Mr. Hubbard's "more than 3400 species," besides "Mollusca," not one in ten have been seen.

able to report concerning them. The first notice of the shells appears in the Proc. Ac. Nat. Sc. Philadelphia, Dec. 1859, pp. 331, 332. The new species are described in the 'Annals and Magazine of Nat. Hist.,' 1864, vols. xiii. and xiv., as follows:—

A. N. H. Vol. XIII.

Sp.	Page.	
1.	311.	*Asthenothærus villosior*, n.g. 1 living sp. and fragm.
2.	,,	*Solemya valvulus.* 1 living sp.
3.	,,	*Tellina* (*Peronæoderma*) *ochracea.* 1 sp.
4.	312.	*Psammobia* (?*Amphichæna*) *regularis.* Valves.
5.	,,	*Callista pollicaris.* 1 sp., living (= *C. prora*, var., teste Rve., C. I. f. 45).
6.	,,	*Callista* (?*pannosa*, var.) *puella.* Extremely abundant, living. Also Acapulco, *Jewett.* (Very variable, yet always differing from the typical South American shells.)
7.	313.	*Liocardium apicinum.* Extremely abundant, living. Also La Paz; Acapulco, *Jewett.*
8.	,,	*Lucina lingualis.* Extremely abundant, valves.
9.	,,	?*Crenella inflata.* Valves; very rare. (An aberrant form.) Also Panama, *C. B. Ad.*
10.	314.	*Bryophila setosa*, n.g. Abundant; living among sea-weed, on *Purpura planospira.* Also California, *Cooper.*
11.	,,	?*Atys casta.* Rare: allied to *Cylichna.*
12.	,,	*Ischnochiton parallelus.* Rare; living.
13.	,,	*Ischnochiton* (?var.) *prasinatus.* 1 living sp. Possibly a form of *parallelus.*
14.	315.	*Ischnochiton serratus.* 1 living sp., like *Elenensis.*
15.	474.	*Nacella peltoides*, = *Nacella*, sp. ind., Maz. Cat., no. 262.
16.	,,	*Acmæa* (?var.) *atrata.* Intermediate between *P. discors*, Phil., and *P. floccata*, Rve. Also La Paz, Margarita Bay.
17.	,,	*Acmæa strigillata.* Intermediate in characters and station between *A. patina* and *A. mesoleuca.* Also Margarita Bay.
18.	475.	*Glyphis saturnalis.* Not uncommon; living.
19.	,,	*Eucosmia variegata.* (Probably a subgenus of *Phasianella.*) Rare, dead.
20.	,,	*Eucosmia* (?*variegata*, var.) *substriata.* Very rare.
21.	,,	*Eucosmia punctata.* 1 sp.
22.	476.	*Eucosmia cyclostoma.* 1 sp.
23.	,,	*Haplocochlias cyclophoreus*, n. g. (?Related to *Ethalia.*) Very rare, dead.
24.	,,	*Narica aperta.* 1 sp.
25.	,,	*Fossarus parcipictus.* 3 sp.
26.	477.	*Fossarus purus.* 1 sp.
27.	,,	*Litorina pullata*, = *Litorina*, sp. ind., Maz. Cat., no. 399. Abundant.
28.	,,	*Litorina* (*Philippii*, var.) *penicillata.* Like the W. Indian *L.* (*ziczac*, var.) *lineata.* Abundant.
29.	,,	*Rissoa albolirata.* 1 sp.
30.	,,	*Fenella crystallina.* 1 sp.
31.	478.	?*Hydrobia compacta.* May be a *Barleeia.* 1 sp.
32.	,,	*Hyala rotundata.* 1 sp.
33.	,,	?*Diala electrina.* 1 sp.
34.	,,	*Acirsa* [teste A. Ad.] *menesthoides.* 1 sp.
35.	,,	*Cythna asteriaphila.* Imbedded in a star-fish, like *Stylina.* 1 living sp.
36.	,,	*Bittium nitens.* 1 sp.
Vol. XIV.		
37.	45	*Mangelia subdiaphana.* 1 sp.
38.	46	*Drillia appressa.* 1 sp.
39.	,,	*Cithara fusconotata.* Very rare.
40.	,,	*Obeliscus variegatus.* 2 worn sp. Described from a fresh Guaymas shell, Mus. Cal. Ac.
41.	,,	(*Odostomia*) *Evalea æquisculpta.* 1 sp.
42.	47.	(*Odostomia*) *Evalea delicatula.* 1 sp.
43.	,,	*Chrysallida angusta.* 1 sp.

A. N. H. Vol. XIV.

Sp.	Page.	
44.	47.	*Eulima fuscostrigata.* 1 sp.
45.	„	*Opalia crenatoides.* 1 perfect and a few rubbed specimens. This, and the Santa Barbara fossil, *O.* ?var. *insculpta,* are so close to the Portuguese *O. crenata,* that additional specimens may connect them.
46.	„	*Truncaria eurytoides.* Common; rubbed. Also Guacomayo, in the Smithsonian Museum.
47.	48.	*Sistrum* (?*ochrostoma,* var.) *rufonotatum*; connected with type by a few intermediate specimens. Rare; dead.
48.	„	?*Nitidella millepunctata.* Also Guacomayo, Mus. Smiths. Very rare, dead.
49.	„	*Nitidella densilineata.* Very rare; dead.
50.	„	?*Anachis tincta.* 1 sp.
51.	49.	*Anachis fuscostrigata,* 1 sp.
52.	„	*Pisania elata.* A few worn specimens; like *Peristernia,* without plait.

The following table contains the species previously described, with the addition of the other localities in which they are known to occur. The numbers in the first column are those in Prof. C. B. Adams's Panama Catalogue: a P in the same column signifies that the species has been found at Panama by other collectors. The second column contains the shells of La Paz, collected by Major Rich and others, and are marked by an italic *P.* In the third column, A shows that the shell has been found at Acapulco, on good authority; and C, that it is known at other stations on the Central American coast. The fourth column exhibits the corresponding numbers of the species in the B. M. Reigen Catalogue; and G shows that the shell has been found in the Gulf district by other collectors. In the fifth column, Cal. stands for Upper, and L for Lower California; Marg. for Margarita Bay, Gal. for the Galapagos, E for Ecuador and the tropical shores of S. America, and WI for the West Indies. The sixth column continues the numbering of the species from the list in the 'Annals.'

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
517		A	14	E	53	*Discina Cumingii.* On *Margaritiphora.*
P			22	E	54	*Gastrochæna ovata.* In *Spondylus.*
		A	23	Marg.	55	*Saxicava pholadis.* In *Spondylus.*
					56	*Eucharis,* sp. ind. 1 dead valve, resembling W. Indian species.
P			35		57	*Sphænia fragilis.* In *Spondylus.*
			G		58	*Thracia squamosa.* 1 broken pair.
	P			L	59	*Thracia* (*Cyathodonta*) *plicata* ("? = *truncata,* Migh."). 1 sp., jun.
P			G		60	*Lyonsia inflata.* 1 sp.
			36	E	61	*Lyonsia picta.* 1 valve.
463	*P*	C	55		62	*Tellina Cumingii.* 1 pair.
469		A		E	63	*Tellina rubescens* [= *Hanleyi*]. Smashed valve.
472					64	*Strigilla sincera.* 1 valve.
		A	67		65	*Strigilla lenticula.* Valves.
P					66	*Lutricola viridotincta.* 2 valves.
485			41		67	*Semele bicolor.* Valves.
			G	Marg.	68	*Semele Californica,* var. Valves.
			40	L	69	*Semele flavescens.* Rare.
480		A	43	E	70	*Cumingia trigonularis,* jun. In *Spondylus.*
473	*P*	A		WI	71	*Heterodonax bimaculatus.* Abundant; normal, and numerous vars.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
		A	75*b*	(Mar.)	72	*Donax*, var. *cælatus*. Valves.
			76		73	*Donax ?Conradi*, jun.
456		C	77	L	74	*Donax ?navicula*, jun.
493	*P*	C	80		75	*Mulinia angulata*. Valves.
	P		79	WI	76	*Standella fragilis*. 1 sp. living, and numerous adult valves.
446	*P*	C	83	E	77	*Trigona radiata*, jun.
					78	*Trigona nitidula*, Sby. Several living sp. agree exactly with Sby.'s figure. [Perhaps Lam.'s Mediterranean shell is different.]
448		C	90	E	79	*Dosinia Dunkeri*. Rare.
	P		88	E.Mar.	80	*Dosinia ponderosa*. Several pairs [jun.=*distans*].
444		A	92		81	*Callista aurantia*.
447	*P*	A	93	E.Mar.	82	*Callista chionæa*.
		C	96	Marg.	83	*Callista vulnerata*. Living, and dead valves.
			98	E	84	*Callista* (?var.) *alternata*. 1 living.
				L	85	*Amiantis callosa*. Rare, living [= *C. nobilis*, Rve.].
	P		G	L.Mar.	86	*Chione succincta*. Very rare.
	P	C		E	87	*Chione pulicaria*, var. *lilacina*. Valves, abundant.
	P	A		E	88	*Chione neglecta*. Living and valves.
			106		88*b*	*Chione undatella*+var. *bilineata*, Rve. (pars). Very rare. [Probably=*neglecta*, var.]
435	*P*	C	113	E	89	*Anomalocardia subimbricata*. Valves.
			111		90	*Tapes squamosa*. 1 sp.
P		A	24	E	91	*Petricola robusta*. In *Spondylus*.
			27		92	*Rupellaria linguafelis*.
			117	E	93	*Crassatella varians*. Living. Large and abundant.
492		C		E	94	*Crassatella gibbosa*. Valves.
	P		118		95	*Lazaria Californica*. Very rare.
		C			96	*Venericardia crassa*. 1 valve.
405		C	121*b*		97	*Chama Buddiana*, jun. On syenitic rock.
407		A	121	E	98	*Chama echinata*, Brod. Living, from Socorro Is.
P		C	121	Marg.	98*b*	*Chama frondosa*, var.
			123	L	99	*Chama ?exogyra*. Worn valves.
	P	A	122	Gal.	100	*Chama spinosa*. 1 sp.
	P	A		E	101	*Cardium consors*. Valves. (Very fine at Acapulco.)
433		C	125	E.Mar.	102	*Cardium procerum*. Valves.
434			126	E	103	*Cardium senticosum*. Valves.
P	*P*	A		L	104	*Hemicardium biangulatum*. Valves.
	P	C	136	WI	105	*Codakia tigerrina*. Living, very large, and young valves. [Of the Pacific Is. type.]
P			137	Pac.Is.	106	*Codakia ?punctata*, jun.
P	*P*	A	147	E	107	*Lucina eburnea*. Living, rare.
P		A	140		108	*Lucina excavata*. 1 valve.
			145		109	*Lucina prolongata*. Valves.
			143		110	*Lucina cancellaris*. Valve.
			G		111	*Diplodonta subquadrata*. 1 sp.
		C			112	*Diplodonta calculus*. Several living sp.
					113	*Miltha Childreni*. [A few fresh specimens correct the habitat "Brazil," previously assigned to this extremely rare and remarkable shell, which appears to be a gigantic *Felania*.]
P		A	153		114	*Kellia suborbicularis*. In *Spondylus*.
		A	154		115	*Lasea rubra*. 6 sp. living.
?		C	167		116	*Mytilus palliopunctatus*. Fragment.
P	*P*	A	168		117	*Mytilus multiformis*. Abundant.
P			169		118	*Septifer Cumingianus*. Common.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No. List of Cape St. Lucas Shells.
	P	A	170	L.Mar.	119 *Modiola capax.* A few living sp. "Gal." [?].
		A	172	Gal.	120 *Crenella coarctata.* In *Spondylus.*
P	.	A	176		121 *Lithophagus aristatus.* In *Spondylus.*
P		A	175		122 *Lithophagus plumula.* In *Spondylus.*
	P	C	181		123 *Arca multicostata.* Adult valves, and jun. living.
P		C	189	E	124 *Byssoarca Pacifica.* Rare.
418		A	190	E	125 *Byssoarca mutabilis.* Valve.
420	*P*			E	126 *Barbatia Reeviana.* Valves.
			192		127 *Barbatia vespertilio.* Valves.
424		C	193		128 *Barbatia illota.* Valve.
423	*P*		195	E	129 *Barbatia solida.* Rare.
416		A	194	E.Mar.	130 *Barbatia gradata.* Valve.
	P		G		131 *Axinæa gigantea.* Large valves, and jun. living.
			696		132 *Axinæa,* sp. ind.
			201	E	133 *Pinna lanceolata.* Fragment.
395			200		134 *Pinna maura.* 1 sp., jun.
P	*P*	A	202		135 *Pinna rugosa.* 1 sp., jun.
391	*P*	C	204		136 *Margaritiphora fimbriata.* Living.
				E	137 *Avicula Peruviana.* Valves.
393	*P*	A	205		138 *Isognomon Chemnitzianus.* Common, living.
			206		139 *Isognomon Janus.* 4 sp. living. [One has close ligament-pits, passing into *costellatus,* just as no. 138, var. passes into *incisus.*]
	P	A	G	E	140 *Pecten subnodosus.* Several valves, and 1 living. [*P. intermedia* is only a var. of this species.]
387	*P*	A	207	E.Mar.	141 *Pecten ventricosus.* Valves. [The young is *P. circularis,* Sby., pars.]
	P		G		142 *Janira dentata.* Very plentiful.
	P				143 *Lima tetrica.* 1 living, and valves [=*L. squamosa,* teste *Cuming.* W. I., Mediter., Pac. Is.].
390				Gal.	144 *Lima arcuata.* 1 fresh pair. [Can hardly be separated from *L. fragilis,* Gal., Pac. Is., in Mus. Cum.]
385			208		145 *Spondylus calcifer.* Valves. Red var., and specimen changing into purple.
386		C	210		146 *Plicatula penicillata.* 1 sp. on *Fasciolaria.*
381		A	211		147 *Ostrea iridescens.* A few living.
383	*P*		212	Marg.	148 *Ostrea ? Virginica,* jun.
			213	E	149 *Ostrea Columbiensis.* Valves.
384	*P*		215	Marg.	150 *Ostrea amara.* On *Pomaulax.*
				Cal.	151 *Cavolina ?telemus.* Fragment. (Pelagic.)
					152–156 [Nudibranchs and *Aplysia.* Not yet determined.]
321	*P*	A	224	E	157 *Bulla Adamsi,* and var. Common.
			225	L	158 *Bulla nebulosa.* Rare.
		A	226	L.Gal.	159 *Bulla Quoyi.* Very rare.
				L	160 *Haminea vesicula.* Plentiful, living.
			229	?L	161 *Haminea cymbiformis.* 1 sp. [Closely related to *H. virescens.*]
			240	Marg.	162 *Siphonaria æquilirata.* Dead. [ful.
P		A	239		163 *Siphonaria lecanium,* with var. *palmata,* &c. Plenti-
					164 *Onchidium Carpenteri.* Very rare.
			235	L.Cal.	165 *Melampus olivaceus.* Rare.
					166–172 [The rest of the Pulmonates will be tabulated afterwards, *vide* p. 630.]
			243		173 *Ianthina decollata.* Very rare.
				L	174 *Ischnochiton Magdalensis.* Large and highly sculptured. Very rare.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
		C	252	E	175	*Ischnochiton limaciformis.* 2 specimens.
			256		176	*Ischnochiton Beanii.* 1 sp.
			258		177	*Acanthochites arragonites.* A few living sp.
		C	261		178	*Patella discors.* Dead.
		A	260		179	*Patella pediculus.* Dead.
			264	Marg.	180	*Acmæa fascicularis.* Abundant, living.
			268		181	*Acmæa mitella*, jun.
	P	A	273	Gal.	182	*Fissurella rugosa*, jun. [A var. is first black, with two white rays; afterwards changes to whitish.]
357		C			183	*Fissurella microtrema.* Common. [Passes into *rugosa.*]
			274		184	*Fissurella nigrocincta.* 1 young sp.
	P	A	279	E	185	*Glyphis inæqualis.* Rare.
			281		186	*Rimula Mazatlanica.* 2 sp.
				L. Cal.	187	*Haliotis Cracherodii.* (Turtle Bay.)
				L. Cal.	188	*Haliotis splendens.* (Margarita Island, with 4, 5, and 6 holes.)
				L	189	*Callopoma Fokkesii.* Dead.
				L. Cal.	190	*Pomaulax undosus.* Fresh, with Gulf Polyzoa.
	P	C	286		191	*Uvanilla olivacea.* Dead.
		A	288		192	*Uvanilla unguis.* Dead.
			289	Marg.	193	*Calliostoma eximium.* Dead.
274	*P*				194	*Omphalius coronulatus.* Dead; not uncommon.
263			295		195	*Vitrinella Panamensis.* 1 sp. off *Spondylus.*
304	*P*	A	326	Marg.	196	*Nerita scabricosta.* Abundant.
305	*P*	C	327	E.Mar.	197	*Nerita Bernhardi.* Abundant.
336	*P*	A	343	E.Mar.	198	*Crucibulum imbricatum.* Dead.
337	*P*	A	344	E.Mar.	199	*Crucibulum spinosum.* Dead.
344	*P*	A	334	E. Cal.	200	*Crepidula aculeata.* Dead. West and East Indies.
	P	A		E.Mar.	201	*Crepidula ? arenata*, jun.*
345		A	337	C.Mar.	202	*Crepidula excavata*, jun. et var.*
346	*P*		340	E.Mar.	203	*Crepidula onyx.* Dead.
328	*P*	A	347	E	204	*Hipponyx antiquatus.* Dead.
327		A	349		205	*Hipponyx barbatus.* Pacific Is. Fresh sp.
329	*P*	A	350	Gal.	206	*Hipponyx Grayanus.* Rare.
323	*P*	A	352		207	*Aletes centiquadrus.* On *Margaritiphora*, &c.
			355		208	*Bivonia contorta.* Frequent, on shells.
		A	359		209	*Petaloconchus macrophragma.* Frequent, on shells.
	P			L	210	*Spiroglyphus lituella.* On *Purpura planospira* and *muricata*, from Socorro Is.
			367		211	*Cæcum subimpressum.* Very rare.
	P	A	380		212	*Turritella tigrina* et var. *Cumingii.*
	P				213	*Turritella sanguinea.* (Whirls not shouldered.)
193	*P*	A	381	Gal.	214	*Cerithium maculosum* and dwarf var., like *medio-læve.* Abundant.
196	*P*	A	383		215	*Cerithium uncinatum.* Common; dead.
200	*P*	A	387	G.Mar.	216	*Cerithium stercus muscarum.* Rare; dead.
	P	A	388	Gal.	217	*Cerithium interruptum*, Mke. Common.
197	*P*	A	389	Marg.	218	*Rhinoclavis gemmata.* Rare.
				Marg.	219	*Pyrazus incisus.* Rare.
?206			395	?E.Mr.	220	*Cerithidea Mazatlanica.* Dead.

* A difficulty attends the identification of young specimens of these rare species, no series having yet been obtained. "*C. excavata*, var.," in Mus. Cum. is exactly intermediate between the two. The young of *excavata* has a large swelling umbo projecting beyond the margin; the umbo in "? var." has the margin spreading round it, as in *onyx*, jun., and in consequence appears turned in the contrary direction. The umbilicus above the deck exists in both forms; but it is not an absolutely constant character, even in *adunca*.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
232		C	397	Marg.	221	*Litorina aspera.* Very rare.
234	*P*	C	396		222	*Litorina conspersa.* Common. A distorted specimen has a Lacunoid chink; another a Nassoid shape.
P			398		28*b*	*Litorina Philippii.* Rare: *v. anteà,* var. *penicillata.*
273	*P*		401	E	223	*Modulus catenulatus,* jun.
244					224	*Rissoina firmata.* Rare.
245					225	*Rissoina fortis.* Very rare.
		A	408		226	*Rissoina stricta.* Rare.
243					227	*Rissoina clandestina.* Dead.
247					228	*Rissoina infrequens.* Dead, worn.
246			414		229	*Alvania tumida.* 1 sp., off *Spondylus.*
		C	417	L	230	*Barleeia subtenuis.* 1 sp.
			411		231	*Barleeia lirata.* 1 sp.
			422		232	*Gemella,* sp. 1 sp.
			420	L	233	*Jeffreysia Alderi.* 1 sp.
			419		234	*Jeffreysia bifasciata.* Very rare.
			425		235	*Alaba supralirata.* Not uncommon.
			427		236	*Alaba terebralis.* 1 dead, broken specimen.
		A	424		237	*Planaxis nigritella.* Dead; some of the specimens may be a dwarf form of
42					237*b*	*Planaxis ? planicostata.*
4			435	?L	238	*Radius variabilis.* 1 sp.
6	*P*	A	438	E	239	*Aricia arabicula.* Very rare.
8	*P*	C		E	240	*Aricia punctulata.* Very rare.
	P				241	*Luponia Sowerbyi.* 1 living and several worn.
	P				242	*Luponia albuginosa.* Dead; plentiful.
						[*Cypræa tigris* and *Pteroceras lambis*; doubtless received through traders.]
9	*P*	A	439		243	*Trivia pustulata.* Dead.
10	*P*	A	440	Gal. E.	244	*Trivia radians*; intermediate specimens towards
P	*P*	A	441		245	*Trivia Solandri.* Dead.
	P	A		Gal.	246	*Trivia Pacifica.* 1 sp.
12	*P*	A	442	E	247	*Trivia sanguinea.* Dead.
		A			248	*Erato Maugeriæ.* [Exactly like the W. Indian specimens: also Crag fossil, teste S. Wood.]
13		A		Gulf E	249	*Erato scabriuscula.* Rare.
122		C	447		250	*Strombus galeatus,* jun. 1 sp.
124	*P*	A	448	Gal. E	251	*Strombus granulatus.* Abundant; dead.
123	*P*		449	E	252	*Strombus gracilior.* 1 dead specimen.
P		C			253	*Subula strigata.* 2 dead specimens.
		C	454	E	254	*Subula ? luctuosa,* jun.
	P	A	455		255	*Euryta fulgurata.* Dead.
		A	456	E	256	*Euryta aciculata.* Dead.
		C			257	*Terebra lingualis.* 1 sp.
	P		G		258	*Myurella variegata.* Very rare.
			450		259	*Myurella albocincta.* 1 dead specimen.
			452		260	*Myurella subnodosa.* 1 dead specimen.
	P	C	457		261	*Pleurotoma funiculata.* Rare; dead.
163			461	E	262	*Drillia aterrima.* Rare; and var. *Melchersi.*
			465		263	*Drillia albovallosa.* 1 sp., dead.
			467	E	264	*Drillia luctuosa.* 1 sp., dead.
	P				265	*Drillia maura,* Val. Fragment.
		A			266	*Daphnella casta.* 1 sp. [Coarser striæ than W. I. species, but scarcely differs from *crebriplicata,* Rve., "Philippines."]
		A			267	*Cithara stromboides* 1 sp. [Probably=*triticea,* Kien.]

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
117	*P*	A		E	268	*Conus princeps.* Dead.
113	*P*	A		Gal. E	269	*Conus brunneus.* Dead.
118	*P*	A	476		270	*Conus purpurascens* and var. *regalitalis.* Dead.
114	*P*	A	480		271	*Conus gladiator.* Dead.
116	*P*	A	481	Gal.	272	*Conus nux* et var. *pusillus* [Gld. non Chem.]. Living; plentiful.
118		C	G		273	*Conus scalaris.* 1 sp., dead.
P	*P*			E	274	*Conus tornatus.* Rare, dead.
270	*P*	A			275	*Solarium granulatum*, and ? var. *quadriceps.* Common.
				L	276	*Odostomia ?straminea.* 1 sp.
			489		277	*Syrnola lamellata.* 1 sp., off *Spondylus.*
254			501		278	*Oscilla exarata=terebellum.* 1 sp.
223			507		279	*Chrysallida communis.* 1 sp., off *Spondylus.*
227			518		280	*Chemnitzia Panamensis.* Very rare.
			519		281	*Chemnitzia Adamsi.* 1 sp., off *Spondylus.*
			524		282	*Chemnitzia prolongata.* 1 sp., off *Spondylus.*
			532		283	*Chemnitzia flavescens.* 1 sp., off *Spondylus.*
194		A	563	L	284	*Cerithiopsis assimilata.* 1 sp., off *Spondylus.*
207			557	L	285	*Cerithiopsis tuberculoides.* 1 sp.
208		C	391		286	*Triforis alternatus.* 1 sp., off *Spondylus.*
P					287	*Scalaria ?tiara.* 1 sp.
295	*P*	A	570	Gal.	288	*Natica maroccana.* Com. W. Afr.; ? Pacific Is.
P	*P*	A			289	*Natica zonaria.* Common. Operc. grooved as in *canrena* [=*alapapilionis*, var., teste Rve.: non Chem.].
		A			290	*Natica catenata.* Common.
302	*P*	A	576	E	291	*Polinices uber.* Common. [The young shells go through all shapes, from globose to pointed. Operc. thin, light green, horny.]
P		A	G	Gal.	292	*Polinices otis* et var. *fusca.* Rare; dead.
	P		G	Marg.	293	*Polinices bifasciata.* Living; rare.
	P	A	G	E	294	*Neverita glauca.* 1 sp.
			577		295	*Lamellaria*, sp. ind. 1 sp.
146		A	579		296	*Ficula ventricosa.* Not uncommon. Animal preserved of both sexes, and of surpassing beauty.
66		C	G	E.Mar.	297	*Malea ringens.* 1 dead sp. [Fossil, Atlantic shores, *Newberry.*]
112	*P*	A	G	Gal.	298	*Oniscia tuberculosa.* Very rare.
111	*P*	A	G	Gal.	299	*Levenia coarctata.* Very rare.
110	*P*	C			300	*Bezoardica abbreviata.* 1 living, with very small normal operculum. Common; dead. [Varies greatly in form and sculpture, like the Texan "analogue," which may be conspecific.]
131		C			301	*Triton vestitus.* 1 sp. [Scarcely differs from *pilearis.*]
132					302	*Ranella cælata.* 1 sp., dead.
				L	303	*Ranella Californica.* Very rare. Grows 4 inches long.
151		A	582	Gal.	304	*Latirus ceratus.* 2 dead sp.
	P		584	E	305	*Fasciolaria princeps.* 2 dead sp.
18		A			306	*Mitra crenata*, Rve., teste Dohrn. 1 sp. [?=*nucleola.*]
19					307	*Mitra solitaria*, C. B. Ad. 1 sp.
20			586	Gal. E	308	*Strigatella tristis.* Rare.
		A	G	E	309	*Æneta harpa.* 1 sp.
P			589		310	*Volutella margaritula.* Off *Spondylus*; common.
14			587		311	*Marginella minor.* Off *Spondylus*; rare.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
		A			312	*Volvarina varia.* Rare. [Cannot be distinguished from some W. I. specimens.]
		A		?WI	313	*Persicula imbricata.* 1 sp. [Can scarcely be separated from *interrupta*, jun. Also Guacomayo.]
					314	*Persicula phrygia.* Rare. [Closely allied to *frumentum.* Differs from the W. I. *sagittata* by having the painting in loops instead of zigzag, and an orange callosity over the sunken spire, bordered by a spotted sutural line.]
36	*P*		G	Marg.	315	*Oliva porphyria.* 1 sp.
?33	*P*	A	591		316	*Oliva Melchersi*, var. Rare.
	P		?592	Marg.	317	*Oliva subangulata.* Very common, dead. [This species, very rare elsewhere, is known by the shouldered shape, toothed paries, and violet-stained mouth and columella.]
	P		600		318	*Olivella dama.* Rare; dead.
	P	C	596		319	*Olivella tergina.* Rare; dead.
39		A	595		320	*Olivella undatella.* 3 sp.; dead.
		C	601		321	*Olivella zonalis.* Rare; dead.
			598	?WI	322	*Olivella v. aureocincta.* 3 sp.; dead.
		A	597	E	323	*Olivella anazora.* Very rare; dead. Perhaps a var. of
34	*P*	A			324	*Olivella gracilis.* Extremely abundant. [With many varieties: among which is one with dark median and sutural bands and light spire; another with dark spire; another pure white, of which the young is *inconspicua*, C. B. Ad. The Acapulcan varieties are somewhat different.]
		A	G		325	*Harpa crenata.* Dead.
76	*P*	A	606	E.Mar.	326	*Purpura biserialis.* Abundant.
	P	A	607		327	*Purpura triserialis.* Common.
69	*P*	A	608	Gal.	328	*Purpura triangularis.* Not uncommon.
	P	A	603	G.Mar.	329	*Purpura patula.* Common. Also West Indies.
P	*P*	C	605	E	330	*Purpura muricata.* Rare; dead at C. S. L.; living at Socorro Island.
	P			Gal.	331	*Purpura planospira.* Dead shells at C. S. L. and La Paz; abundant and fine at Socorro Island.
74			611		332	*Rhizocheilus nux*+tall var. [= *Californicus.*]
107		A		Gal.	333	*Sistrum carbonarium.* Living; plentiful.
89	*P*	A	613	WI	334	*Nitidella cribraria.* Abundant.
94		A	615	E	335	*Columbella major.* Rare.
86	*P*	A	617	E	336	*Columbella fuscata.* Abundant.
		A			337	*Columbella festiva.* Not rare.
90	*P*			Gal.	338	*Columbella hæmastoma.* Not rare.
				E	339	*Columbella solidula.* Abundant *.
		A		E	340	*Columella Reevei* [= *Sta. Barbarensis*, Cpr. (error)].
				E	341	*Columella baccata.* Rare.
	P				342	*Conella cedonulli.* 1 sp.
	P		624	L.Mar.	343	*Nassa tegula.* Rare; pale var.
55		C	632		344	*Nassa versicolor.* Rare; dead.
45	*P*	A			345	*Nassa corpulenta.* Very rare.

* The young shell is thin, semitransparent, with Alaboid tuberous vertex. The nuclear part is rather more tumid than the next whirl, and set slanting as in some *Chrysodomi*. Adolescent, whirls smooth, except a sutural line. Sculpture of adult gradually developed, with spiral lines, sometimes all over, sometimes only anteriorly and posteriorly. Last whirl sometimes with blunt radiating riblets, but generally smooth. Siphonal notch deeply cut back, as in *Strombina*, to which the species may belong.

Pan. Cat.	La Paz.	Aca-pul.	Maz. Cat.	Other habitats.	No.	List of Cape St. Lucas Shells.
	P			Gal.	346	*Fusus Thouarsii* [+*Novæ-Hollandiæ,* Rve.]. Rare; dead.
	P		639	E	347	*Siphonalia pallida.* Very rare.
109				Gal.	348	*Engina Reeviana.* 1 sp.
P		A		Gal.	349	*Engina crocostoma.* 1 sp.
P		C	647		350	*Anachis coronata.* Very rare.
			652	E	351	*Anachis tæniata* [= *Gaskoinei*]. Very rare.
99					352	*Anachis pulchrior.* Very rare.
			G		353	*Anachis ?pallida,* Phil. Very rare.
98				E	354	*Anachis ?parva,* var. Dead shells: may be *pygmæa,* var.
			650		355	*Anachis serrata.* A few perfect specimens.
(100)		A	(651)	(E)	356	*Anachis pygmæa* (var. *auriflua*). Rare.
	P	C	657		357	*Strombina maculosa.* Very rare.
87				E	358	*Strombina gibberula.* Very rare.
64	*P*	A	662		359	*Pisania sanguinolenta.* Dwarf var.; common.
60		A			360	*Pisania lugubris.* Rare; dead.
	P	C	664		361	*Murex plicatus.* Rare; dead.
140	*P*	A	665		362	*Murex recurvirostris.* 1 sp., dead.
	P	A	669		363	*Phyllonotus bicolor.* Rare.
	P	A	671		364	*Phyllonotus princeps.* Rare; dead.
136	*P*	A	673		365	*Muricidea dubia.* Rare; dead.
					366	*Argonauta argo.* 1 large sp. of the ?var. *papyracea.* Pelagic.
					367	*Octopus,* sp. Pelagic.

As would be expected, the bulk of these species (203 out of 367) are the same as have been already enumerated in the Reigen Catalogue. Of those which do not appear in the Mazatlan lists, no fewer than 37 appear in the Panama collections (beside 10 others, known to inhabit the equatorial region). Of those not quoted from Mazatlan, 34 are also found in the Acapulco region, and 30 at La Paz. Of the whole number, 79 have also been found in South America, and 28 in the Galapagos. 38 have also been found in Margarita Bay, of which *Pyrazus incisus* and *Siphonaria æquilirata* are Lower Californian rather than Gulf species; but only 13 belong to that portion of the Lower Californian fauna which is known to reach S. Diego, exclusive of the same number of Gulf species, which also stray into the S. Diegan district. There are also 10 species, which (with more or less distinctness) represent West Indian forms. Of these, five, viz. *Heterodonax bimaculatus, Erato Maugeriæ, Volvarina varia, Persicula imbricata* and *phrygia,* are new to the Gulf fauna: the other five appear in the Reigen Catalogue.

106. The most extensive collections in the Vancouver district, both as far as the number of species and of specimens is concerned, have been made for the Smithsonian Institution by Mr. J. G. Swan, teacher at the Indian Reserve, Neeah Bay, W. T. For several years * valuable consignments have been received from him of shells collected at Cape Flattery, Port Townsend, and other stations. Latterly he has trained the native children to pick up shore-shells in large quantities. The labour of sorting and arranging these has been enormous; it has, however, been repaid not only by observing the

* In consequence of boxes having been received at different times, through the accidents of transit, it has not always been possible to ascertain with certainty to whom, among simultaneous collectors, should be allowed priority in the discovery of new species.

variations of form in large numbers of individuals, but by the discovery of several new species and the addition to the district-fauna of many others. The duplicates are made-up in series for distribution by the Smithsonian Institution; and, though of the worst quality from a "collector's" point of view, they will be found very serviceable by real students, being carefully named in accordance with this Report. He has now received a dredge, constructed for him by Dr. Stimpson; and if he succeeds in training the young Indians to use it, there is little doubt that a rich harvest of fresh materials will shortly be obtained. Some of the collections were made on the neighbouring shores of Vancouver's Island, among which was a large series of *Pachypoma gibberosum*, Chem., with attached *Bivonia*, both of an essentially Eastern Pacific type, the former having been brought from Japan by Mr. A. Adams. The Indians have taken a fancy to the opercula of this shell for the purpose of ornamenting their canoes. As it is an article of trade among themselves, it is remarkable that so large a shell should have so long escaped the notice of collectors. Dead specimens have been washed-up in California; but it is not known even to enter the Straits of De Fuca alive. The shore-pickings of the Indian children, which have already added 25 species to science, are singularly free from ballast-importations, although they present a few (supposed) extra-limital shells, probably washed-up by the ocean currents. The following are the species new to the Vancouver fauna; the remainder will be found tabulated in the 7th column of the general Table, par. 112, *infrà*.

No.
1. *Waldheimia Coreanica*, valves.
2. *Xylotrya pennatifera*, teste Jeffr.
3. *Clidiophora punctata*, one worn valve.
4. *Macoma ? edentula.* Two living shells may be the young of this species, or an extreme var. of *inquinata.*
5. *Mæra salmonea.* Plentiful.
6. *Angulus variegatus.* Rare.
7. *Semele rubrolineata.* One large valve may belong to this species, or (more probably) be distinct and new.
8. *Standella ? Californica.* One young valve.
9. *Miodon prolongatus*, n. subg., n. s. Several valves of this curious shell, intermediate between *Lucina* and *Venericardia*, accord with forms not before eliminated, from the Coralline Crag and Inferior Oolite.
10. *Lazaria subquadrata.* One valve.
11. *Diplodonta orbella.* Very large valves.
12. *Kellia* (var.) *Chironii.* A few valves.
13. *Adula stylina.* Plentiful.
14. *Axinæa* (? *septentrionalis*, var.) *subobsoleta.* Numerous valves.
15. *Siphonaria Thersites*, n. s. Rare, dead. Like *tristensis* and other Cape Horn and N. Zealand types. The genus was not known north of Margarita Bay.
16. *Mopalia* (*Kennerleyi*, var.) *Swannii.* One sp. and valves.
17. *Ischnochiton* (*Trachydermon*) *Nuttallii.* One sp.
18. *Haliotis Kamtschatkana.* Rare.
19. *Pachypoma gibberosum*, Chem. Living; plentiful.
20. *Leptonyx sanguineus*, Linn. Very plentiful. (Japan, *A. Ad.*; = *Homalopoma sanguineum*, anteà p. 588 (nom. preoc.); Mediterranean, *Philippi.*)
21. *Chlorostoma funebrale* (et var. *subapertum.* One sp.).
22. *Calliostoma canaliculatum.* Living; abundant.
23. *Margarita cidaris*, n. s. One fresh specimen, with aspect of *Turcica.*
24. *Margarita helicina.* Very rare.
25. *Gibbula parcipicta.* One sp.
26. *Gibbula succincta*, n. s. Rare.
27. *Gibbula lacunata*, n. s. One sp.

No.
28. *Gibbula funiculata*, n. s. Very rare.
29. *Hipponyx cranioides*, n. s. Plentiful.
30. *Bivonia compacta*, n. s. Frequent on *Pachypoma*; externally resembles *Petaloconchus macrophragma.*
31. *Bittium* (?var.) *esuriens.* Common, dead.
32. *Lacuna porrecta*, n. s. Plentiful, with intermediate ?vars. *exæquata* and *effusa.*
33. *Lacuna* (?*solidula*, var.) *compacta.* Rare.
34. *Lacuna variegata*, n. s. Not common; resembles the Japanese *L. decorata.*
35. *Isapis fenestrata*, n. s. Very rare.
36. *Alvania reticulata*, n. s. Very rare.
37. *Alvania filosa*, n. s. One specimen.
38. ?*Assiminea subrotundata*, n. s. One specimen.
39. ?*Paludinella*, sp. One specimen.
40. *Mangelia crebricostata*, n. s. Very rare.
41. *Mangelia interfossa*, n. s. Several dead specimens.
42. *Mangelia tabulata*, n. s. Several dead specimens.
43. *Daphnella effusa*, n. s. One broken specimen.
44. *Odostomia satura*, n. s. and ?var. *Gouldii.* Very rare.
45. *Odostomia nuciformis*, n. s. and ?var. *avellana.* Very rare.
46. *Odostomia inflata.* Very rare.
47. *Odostomia tenuisculpta*, n. s. Very rare.
48. *Scalaria Indianorum*, n. s. Rare.
49. *Opalia borealis.* Very common. This fine species, indicated by Dr. Gld. (E. E. Mol., p. 307) under *Scalaria australis*, closely resembles *O. Ochotensis*, Midd. It is not referred to in the 'Otia,' and the locality was naturally suspected.
50. *Cerithiopsis munita*, n. s. Rare.
51. *Cerithiopsis columna.* Very rare.
52. *Cerithiopsis tuberculata.* } Rare. No differences have been detected on comparing
53. *Triforis adversa.* } the Herm and Neeah Bay specimens.
54. *Trichotropis inermis.* A few specimens differ from the decorticated *T. cancellata*, and agree with Hinds's diagnosis.
55. *Cancellaria modesta*, n. s. One sp. and fragment.
56. *Velutina prolongata*, n. s. Very rare.
57. *Olivella biplicata.* Very fine and abundant.
58. *Purpura* (var.) *fuscata.* Forbes's species, the locality of which was before uncertain, is here connected by easy transitions with the normal *saxicola.*
59. *Columbella* (var.) ?*Hindsii.* May be a stunted form of *A. gausapata.*
60. *Amycla tuberosa.* Rare.
61. *Chrysodomus tabulatus.* One beautifully perfect specimen; described and figured from Mr. Lord's broken shell, sent simultaneously.

The following appear to be due to currents:—

62. *Pachydesma crassatelloides.* Fragment.
63. *Fissurella volcano.* One broken specimen.

107. A collection of shells received from the Farallones Islands by Mr. R. D. Darbishire, of Manchester, soon after the publication of the first Report, contained several species at that time new to science, but in too imperfect a condition for description. Among them were—

Martesia intercalata, Maz. Cat., no. 19. Burrowing in *Haliotis rufescens.*
Odostomia inflata, n. s. Young shells, abundant, in *Haliotis rufescens.*
Ocinebra lurida.
Ocinebra interfossa, n. s.

Collections from the same locality were afterwards sent by the Rev. J. Rowell, and are tabulated with the rest of the Smithsonian series in the 4th column of the general Table, par. 112.

108. In 1860, previously to the commencement of the Californian Geological Survey, Dr. J. G. Cooper joined a military expedition across the Rocky Mountains, under the command of Major Blake, U.S.A. Having forwarded his notes and specimens to Judge Cooper, they were placed in the hands of Mr. Thomas Bland, of New York. He prepared a "Notice of Land and Freshwater Shells, collected by Dr. J. G. Cooper in the Rocky Mountains, &c.," which appears in the 'Ann. Lyc. N. H. of N. York,' 1861, pp. 362 *et seq.* We have here the judgment of one of the most distinguished students of American land-shells, whose labours on the tropical forms have accumulated facts so important in their bearing on the Darwinian controversy *. The following is an outline of the Report, which is peculiarly valuable for the copious notes on the station and distribution of species:—

No.

1. *Helix Townsendiana*, Lea. "Both slopes of the Bitter Root Mountains, from 2200–5600 ft. high. Large var. at the base of the range to 4800 ft. Small var. in dry prairie at junction of Hell-Gate and Bitter Root Rivers; also in Wash. Ter., west of the Coast Mountains. The most wide-spread of the species," *J. G. C.*; Puget Sound, Cape Disappointment, teste *Bland.*
2. *Helix Mullani*, n.s., Bland. "Under logs and in dry pine-woods: dead, Cœur d'Alêne Mission: living, west side of Bitter Root Mountains," *J. G. C.*; St. Joseph's River, 1st Camp, Oregon, teste *Binney.* Closely allied to *H. Columbiana*, Lea, = *labiosa*, Gld. A beautiful hyaline var. was found under a stone, by the Bitter Root River, 4000 ft. high.
3. *Helix polygyrella*, n.s., Bland. "Moss and dead wood in dampest parts of spruce-forests; common on the Cœur d'Alêne Mountains, especially eastern slope," *J. G. C.* Entirely unlike any other N. A. species, and having affinity with *H. polygyrata* from Brazil.
4. *Helix Vancouverensis*, Lea, = *H. concava*, Bin. sen. olim, non postea, nec Say; = *H. vellicata*, Fbs., certainly; = *H. sportella*, Gld., probably. "West side of Cœur d'Alêne Mountains, W. T., in forests of Coniferæ, such as it inhabits west of the Cascade Range. Between these two ranges, for 200 miles, is a wide plain, quite uninhabitable for snails, on account of drought. This sp. and *H. Townsendiana* probably travel round it through the northern forests in lat. 49°," *J. G. C.* Also Crescent City, Cal., *Newcomb*; Oregon City, Whidby's Is., W. T.; Mus. Bland. Found on the Pacific slope, from Puget Sound to San Diego.
5. *Helix strigosa*, Gld. "Æstivating under pine-logs, on steep slope of shale, containing veins of lime, 4000 ft. high, near Bitter Root River, Rocky Mountains," *J. G. C.*; Big Horn Mountains, Nebraska; Rio Piedra, W. New Mexico; teste *Bland.* One sp. reached N. York alive, and deposited six young shells. [?May not these have been abnormally hatched in the body of the parent, from the unnatural confinement.]
6. *Helix Cooperi*, Binn., jun. "East side of Mullan's Pass, Rocky Mountains, W. T., at an elevation of 5500 ft.," *J. G. C.*; Black Hills of Nebraska, *Dr. V. Hayden*; Big Horn Mountains, Nebraska; west side of Wind River Mountains; Rio Piedra, W. N. Mexico, teste *Bland.* Passes by varieties towards *H. strigosa*, Gld. Hayden's shell from Bridger's Pass, Nebr., referred to by Binn., jun., Journ. A. N. S. Phil. 1858, p. 115, as *H. solitaria*, var., is the young of this species.
7. *Helix solitaria*, Say. Both slopes of Cœur d'Alêne Mts., 2500 feet high, *J. G. C.* Also Prairie States, teste Bland.
8. *Helix arborea*, Say. "Damp bottom lands, along the lower valley of Hell-Gate River, 4500 ft. high," *J. G. C.* Found from Labrador to Texas, and from Florida to Nebraska; also on the River Chama, N. Mex.; also Guadaloupe, teste *Beau* and *Férussac*, letter to Say, 1820; teste *Bland.*

* *Vide* "Geographical Distribution of the Genera and Species of Land Shells of the West Indies, &c.," by Thomas Bland. Reprinted from Ann. Lyc. Nat. Hist., vol. vii. New York, 1861.

No.
9. *Helix striatella*, Anth. With *H. arborea*, *J. G. C.* From Canada E. to Kansas, and from Pembina (Red River N.) to Virginia; teste *Bland.*
10. *Succinea rusticana*, Gld. "Rocky Mountains of Bitter Root Valley, 2500–4500 ft.," *J. G. C.*

The freshwater shells collected on the Rocky Mountains by Dr. Cooper were determined, with the assistance of Dr. Lea and of Messrs. Binney and Prime, as follows:—

11. *Limnæa fragilis* [as of] Linn. [Binney]. Hell-Gate River; Missouri River, above the Falls. [=*L. palustris*, auct.]
12. *Limnæa humilis*, Say. Hell-Gate River.
13. *Limnæa bulimoides*, Linn. [Binney]. Missouri River, above the Falls.
14. *Limnæa desidiosa*, Say. Missouri River, above the Falls.
15. *Physa hypnorum*, Linn. Hell-Gate River.
16. *Physa heterostropha*, Say. Hell-Gate River; Missouri River, above the Falls.
17. *Planorbis trivolvis*, Say. Hell-Gate River.
18. *Planorbis ?parvus*, Say. Hell-Gate River.
19. *Ancylus*, sp. ind.
20. *Melania plicifera*, Lea. Hell-Gate River.
21. *Leptoxis*, sp. ind.
22. *Amnicola*, sp. ind.
23. *Sphærium* [*Cyclas*] *occidentale*, Prime. Hell-Gate River.
24. *Sphærium* [*Cyclas*] *striatinum*, Lam. Missouri River, above the Falls.
25. *Unio luteolus*, Lam.
26. *Margaritana margaritifera*, Linn. Missouri River, above the Falls; also Spokan River, below Lake Cœur d'Alêne, =*A. falcatus*, Gld.; the purple var. hitherto only found on the Pacific slope.

109. The land-shells of the peninsula of California present points of great interest to the student of geographical distribution. While those of the eastern shore of the Gulf belong exclusively to the Mexican or Central American fauna, those of the western present in their general features that form of the South American type which belongs to the region of the Andes. The contrast between the Glandinæ and painted Bulimids of Mazatlan, and the small dull forms, or solid white shells of the peninsula, is evident even to the superficial observer. They are catalogued by Mr. Binney in the 'Proc. Ac. Nat. Sc. Philadelphia,' 1861, pp. 331–333, and are as follows, outline-figures being given of the new species:—

No.
1. *Helix areolata*, Sby. Cerros Is., *Dr. Veatch.*
2. *Helix Pandoræ*, Fbs. Margarita Is. (*Binney*).
3. *Bulimus excelsus*, Gld. La Paz. (Mus. Cal. Acad. N. S.)
4. *Bulimus vesicalis*, Gld. Lower California. [Altered in 'Otia,' p. 184, to *B. sufflatus*; nom. preoc.]
5. *Bulimus pallidior*, Sby., =*vegetus*, Gld. With *B. incendens*, v. infrà. (S. America, *Cuming.*) [Cape St. Lucas List, no. 166.]
6. *Bulimus proteus*, Brod. One large and many young specimens; Cape St. Lucas, *Xantus.* (Mountains of Peru, teste *Pfeiffer.*) [C. S. L., no. 167.]
7. *Bulimus Xantusi*, n.s. Promontory of St. Lucas. 4 sp. *Xantus.* [No. 168.]
8. *Bulimus artemisia*, n.s. Promontory of St. Lucas. 1 sp., on small species of *Artemisia*; *Xantus.* [C. S. L., no. 169.]
9. *Bulimus pilula*, n.s. Todos Santos Mission and Margarita Is., in rocky spots under mosses, not uncommon, *Xantus.* Resembles *B. sufflatus*, jun. [No. 170.]
10. *Bulimus incendens*, n.s. In great numbers with *B. pallidior*, Sby., climbing high "copal" or copaiva trees, on dry hills 800–1000 ft. high; Cape St. Lucas, Margarita Bay, *Xantus.* Resembles *B. excelsus*, Gld. [No. 171.]
11. *Pedipes lirata*, Binn. Cape St. Lucas, *Xantus.* [C. S. L., no. 172.]

110. At the time of the preparation of the first Report, not a single naturalist was known in Europe to be resident on the western slope of North America, to whom communications could be addressed on the subject of it. There was, however, even at that time, a "Californian Academy of Natural Sciences," which met at S. Francisco, and published its 'Proceedings.' This Academy is now in a flourishing condition, under the presidency of Col. L. Ransom. The general zoological department is under the care of Dr. J. G. Cooper; the shells under that of Dr. J. B. Trask, Vice-President of the Academy, whose name has already appeared in Judge Cooper's Report, *anteà*, p. 597; and the fossils under that of Mr. W. M. Gabb. The corresponding secretary is Dr. W. O. Ayres; and the librarian Prof. J. D. Whitney, the director of the State Geological Survey. Already the nucleus has been formed of a very valuable collection, many of the critical species in which have been sent to England for identification. The coasting-trade between S. Francisco and many stations in L. California, the Gulf, and the Mexican coast, offers peculiar facilities for obtaining valuable information. Two of the contributors to the Californian Academy require special and grateful mention. Dr. Wesley Newcomb (whose labours had greatly enriched the State Collection at his native city, Albany, New York, and whose researches among the *Achatinellæ* in the Sandwich Islands are well known) is stationed at Oaklands, near Francisco, and has already furnished valuable papers, an abstract of which is here given, as well as emendations and additions to the British Association Report, which are included in their appropriate places*. The Rev. J. Rowell has long been a regular correspondent of the Smithsonian Institution, and has submitted the whole of his West-coast collections for analysis. He has displayed peculiar industry in searching for small species on the backs of the larger shells, especially the Haliotids of the Californian coast, and the *Ostrea iridescens*, which is imported in large quantities from Acapulco for the San Francisco market†.

In the 'Proc. California Ac. Nat. Sc.,' vol. i. pp. 28–30, Feb. 1855, Dr. J. B. Trask published descriptions of *Anodonta Randalli*, Trask, Upper San Joaquin; *Anodonta triangularis*, Trask, Sacramento River; *Anodonta rotundovata*, Trask, Sacramento Valley; *Alasmodonta Yubaënsis*, Trask, Yuba River.

In the 'Ann. Lyc. N. H. New York,' vol. vii. 1860, p. 146, Dr. Newcomb describes the first *Pupa* found on the Pacific slope, viz. *Pupa Rowellii*, Newc. Near Oakland, Cal. "Approaches nearest to *P. ovata*, Say."

* The "*Chiton amiculatus*," Newc., MS., = *Cryptochiton Stelleri*. "Rare near S. Francisco; somewhat more abundant in the Bay of Monterey." His "*Panopæa generosa*," in the Albany Museum, was found to be *Schizothærus Nuttallii*.

† As an instance of the way in which mistakes arise, may be placed on record a series of shells sent to Mr. Rousseau, of Troy, New York, by Mr. Hilman, formerly of that city, now a resident at San Francisco. They were sent as Californian; yet, of the thirty-four species which it contained, only one could be called a native of that province. All the rest were tropical, and of that peculiar character which belongs to Acapulco. No doubt, the gentleman had obtained them from a trader to that city. If only a few species had been sent, mixed with Californian shells, they might have puzzled the learned; for they were obtained, on the spot, by a gentleman of known integrity. As it was, the magnitude of the error led to its discovery: but in how many similar cases such error is thought impossible!—*Strigilla carnaria*; *Donax carinatus, puncto-striatus*; *Heterod. bimaculatus*; *Callista aurantia, chionæa*; *Petr. robusta*; *Card. consors, biangulatum*; *Liocard. apicinum*; *Trigona radiata, Hindsii*; *Anom. subimbricata*; *Lima tetrica*; *Siphonaria gigas, lecanium*; *Patella discors, pediculus*; *Fiss. rugosa*; *Cruc. imbricatum, spinosum, umbrella*; *Crep. aculeata*; *Hipp. antiquatus, barbatus*; *Cerith. uncinatum*; *Modulus disculus*; *Natica maroccana, catenata*; *Polinices uber*; *Leuc. cingulata*; *Æneta harpa*; *Purp. triangularis.* The single shell from the temperate fauna is *Glyphis aspera*, which has not yet been found so far south as San Francisco.

In the 'Ann. Lyc. N. H. New York,' 1861, p. 287, the Rev. J. Rowell, of San Francisco, describes the second species of *Pupa** discovered on the western slope, viz. "*P. Californica*, Row., San Francisco: plentiful."

On February 4th, 1861, Dr. Wesley Newcomb published (Latin) diagnoses of the following Californian Pulmonates in the 'Proceedings of the Cal. Ac. Nat. Sc.,' vol. ii. pp. 91–94. A second Part bears date March 18th, pp. 103, 104.

Page.
91. *Helix Bridgesii*, Newc. San Pablo, Cal. 1 sp. Distinct from all described forms.
„ *Helix Traskii*, Newc. Los Angelos, Cal. "Distinguished from *H. Thouarsii* at a glance."
92. *Vitrina Pfeifferi*, Newc. Carson Valley. More rounded than *diaphana*, Drap.
94. *Pisidium occidentale*, Newc. Ocean House, S. Francisco, *Rowell.*
103. *Helix Carpenteri*, Newc. Tulare Valley, Mus. Cal. Ac. Belongs to the Cyclostomoid group, and has the aspect of a desert species. [Quite distinct from *H. Carpenteriana*, Bland, Florida.]
„ *Helix Ayresiana*, Newc. Northern Oregon; Mus. Cal. Ac. Resembles *H. reticulata*, Pfr., a Californian species not identified by the author.
104. *Physa costata*, Newcomb. Clear Lake, Cal., *Veatch*, Mus. Cal. Ac.

In the 'Proc. Ac. Nat. Sc. Philadelphia, 1861,' pp. 367–372, Mr. W. M. Gabb published "Descriptions of New Species of American Tertiary Fossils," in which occur several Californian shells. The authorities for the localities are not given, and the diagnoses are in English only. Considerable confusion often arises from the study of tertiary fossils without knowledge of recent shells, and *vice versâ*. Mr. Gabb's writings on the Cretaceous fossils of America display an ability with which this paper is perhaps not commensurate. Some errors which had been found very difficult to understand are here corrected by the author himself, who regrets the incompleteness of his earlier work.

368. *Turbonilla aspera*, Gabb. Sta. Barbara, Miocene. [=*Bittium*, sp., teste *Gabb*, MS.]
„ *Modelia striata*, Gabb. Sta. Barbara, ?Miocene. [=*Lacuna carinata*, Gld. teste *Gabb* MS. and specimens. Mr. Gabb considers that *Litorina Pedroana* Conr., is the same species, which is probably not correct.]
369. *Sphenia bilirata*, Gabb. Sta. Barbara. [Description accords with *Saxicava arctica*, jun., var.; but Mr. Gabb considers it a good species.]
„ *Venus rhysomia*, Gabb. ? Miocene, Sta. Barbara. [=*Psephis tantilla*, Gld., teste *Gabb* MS. and specimens.]
371. *Cardita monilicosta*. ? Miocene, Sta. Barbara. [Description accords with *Venericardia ventricosa*, Gld. jun.; but Mr. Gabb considers it a good species.]
„ *Morrisia Hornii*. ?Miocene. Sta. Barbara. "First pointed out by Dr. Horn in a rich fossiliferous marl, and not uncommon."

In the 'Proceedings of the Calif. Ac. Nat. Sc.' for April 7th, 1862, pp. 170–172, Mr. W. M. Gabb published detailed English "Descriptions of two Species of Cephalopoda in the Museum of the Academy," of which one, *Onychoteuthis fusiformis*, is said to be from Cape Horn, the other from California.

170. *Octopus punctatus*, Gabb. Common near San Francisco. Also abundant in Scammon's Lagoon, Lower California, *Capt. C. M. Scammon.* Arms more than seven feet long, *Dr. W. O. Ayres.* "Differs from *O. megalocyathus*,

* That the race of small *Pupæ* is very ancient on the North American continent, as in Europe, is evident from the very interesting discovery, by Prof. Dawson, of a fossil *Pupa*, *in situ*, nestling in an upright tree, fossilized in the Nova Scotian coal-beds; which can scarcely be distinguished, even specifically, from some living forms.

Page.

Couth., E. E. Moll. p. 471, in absence of lateral membrane, size of mouth and cupules, and general coloration."

171. *Onychoteuthis fusiformis*, Gabb. "Cape Horn," Mus. Ac. [San Clemente Is., Cal., *Cooper*, MS.]

From the 'Proc. Cal. Ac. N. S.,' 1863, p. 11, it appears that at least one mollusc, a *Teredo* or *Xylotrya*, has already established for itself an economic celebrity. Piles have been entirely destroyed in six months from the time they were placed in the water.

On March 2, 1863, Mr. Auguste Remond published, in the same Journal, English "Descriptions of two new Species of Bivalves from the Tertiaries of Contra Costa County:"—

13. *Cardium Gabbii*, Rem. Late tert. deposit near Kirker's Pass, in shelly sand, with *Tapes regularis*, Gabb, and *Murex ponderosus*, Gabb, both extinct. "Easily recognized by heavy hinge and enormous laterals; lunule carinated." [? *Liocardium.*]

„ *Ostrea Bourgeoisii*, Rem. Same locality.

On April 20, 1863, Dr. Cooper described (in English) the following mollusc, of which the only species previously known is from Cuba:—

21. *Gundlachia Californica*, Rowell. Fig. 5 (three views). Fifty specimens on water-plants in clear, stagnant ponds, at Marysville, Feather River, *Rowell.*

On January 8, 1864, Dr. Newcomb described (in Latin) the following, with other Pulmonates from the State Survey, already tabulated in p. 609:—

115. *Helix Hillebrandi*, Newc. Tuolumne Co., Cal. One recent and several fossi shells, *M. Voy.* Like *H. Thouarsii*, but depressed and hirsute.

The latest contribution to the malacology of California is one of the most interesting. It is described (in Latin) by Dr. Newcomb, Feb. 1, 1864:—

121. *Pedicularia Californica*, Newc. One specimen from coral growing on a monster *Echidnocerus*, very deep water, Farallones Is., *D. N. Robinson.* "As beautiful as *P. elegantissima*, Desh., from Is. Bourbon." [Mr. Pease also obtained a deep-water *Pedicularia* from coral in the Pacific Is., which Mr. Cuming affiliated to the Mediterranean *P. Sicula.* Dr. Gould (Otia, p. 215) also describes *P. decussata*, coast of Georgia, 400 fm., U. S. Coast Survey.]

111. The following descriptions of species, and notes on habitats and synonymy, have been collated from various American scientific periodicals, chiefly by the assistance of Mr. Binney's 'Bibliography.'

In the 'American Journal of Science and Art,' O. S., vol. xxxviii. p. 396, April 1840, Dr. A. A. Gould records the following species, said to be from "California." His *Trochus vittatus* is not known:—

Murex tricolor et bicolor.	Trochus vittatus.
Cardium Californianum.	Bulimus undatus.

In the 'Annals of the New York Lyceum of Natural History,' vol. iv. 1846, No. 5, p. 165, Mr. John H. Redfield first described *Triton Oregonense*, Straits of San Juan de Fuca: plate 11. fig. 2.

In the 'Proceedings of the Academy of Natural Sciences of Philadelphia,' 1848, vol. iv. p. 121, Mr. T. A. Conrad described new genera, and gave notes on *Parapholas Californica*, *Cryptomya Californica*, and *Psammobia Californica*, altering *Osteodesma hyalina* (nom. preoc.) into *Lyonsia Floridana.* In the same work, March 1854, vol. vii., Mr. Conrad described *Cyathodonta undulata.* He also states that *Gnathodon trigonum*, Petit, is probably identical with *G. Lecontei*, Conr. [?] (nom. prior), and alters genus *Trigonella* to *Pachydesma.*

In the 'Proc. Boston Ac. Nat. Hist.,' July 1851, vol. iv. p. 27, Dr. A. A. Gould published "Notes on Californian Shells," and, in vol. vi. p. 11, described *Helix ramentosa*, California, and *Helix damascenus*, from the desert east of California.

In the 'Proceedings Ac. Nat. Sc. Phil.,' April 1856, vol. viii. pp. 80, 81, Dr. Isaac Lea described the following species of new freshwater shells from California:—

Pompholyx effusa. Sacramento River.
Melania Shastaënsis. Shasta and Scott Rivers.
Melania nigrina. Clear Creek, Shasta Co.
Physa triticea. Shasta Co.
Planorbis Traskii. Kern Lake, Tulan Co.
Lymnæa proxima. Arroya, St. Antonio.
Ancylus patelloides. Sacramento River.

and offered notes on

Margaritana margaritifera, Lea, = *Alasmodonta falcata*, Gld., = *Alasmodonta Yubaënsis*, Trask. Klamath and Yuba.
Anodonta Wahlamatensis, Lea, = *A. triangulata*, Trask, + *A. rotundovata*, Trask. Sacramento River.
Anodonta angulata, Lea, + *A. feminalis*, Gld., + *A. Randalli*, Trask. Upper San Joaquin.
Helix Oregonensis, Lea. Point Cypress, Monterey Co.
Helix Nickliniana, Lea. Tomales Bay and Dead Man's Island.
Helix Californiensis, Lea. Point Cypress.
Lymnæa exigua, Lea. San Antonio Arroya.
Lymnæa pallida, Ad. San Antonio Arroya.
Physa heterostropha, Say. Los Angeles.
Melania occata, Hds. Sacramento River.
Melania (Paludina) seminalis, Hds. Sacramento River.
Planorbis trivolvis, Say. Horn Lake.
Planorbis ammon, Gld. Lagoons, Sacramento Valley.

In the New Series of the 'Proc. Ac. Nat. Sc. Philadelphia' occur descriptions and notes on species, as under:—

		Page.	
1857.	Feb.	18.	*Helix intercisa*, W. G. Bin., = *H. Nickliniana*, Bin. sen., var. Oregon.
1857.	,,	19.	*Succinea lineata*, W. G. Bin. Nebraska.
1857.	June.	165.	Mr. T. A. Conrad described the genus *Gonidea* for *A. angulata*, Lea; and for *Gonidea Randalii*, Trask, and *Gonidea feminalis*, Gld.; regarding the three species as probably distinct. [Dr. Lea, however, considers them varietal.]
1858.	March.	41.	Dr. I. Lea described *Planorbis Newberryi*. Klamath Lake and Canoe Creek, California.
1860.	March.	23.	*Melania Newberryi*, Lea. Upper Des Chutes River, Oregon, *Newberry*.

In the "Notes on Shells, with Descriptions of New Genera and Species," by T. A. Conrad, reprinted from the 'Journ. Ac. Nat. Sc. Phil.,' Aug. 1849, are given the following synonyms, pp. 213, 214:—

Petricola Californica, Conr., = *Saxicava C.*, Conr., = *P. arcuata*, Desh.
Petricola carditoides, Conr., = *Saxicava c.*, Conr., = *P. cylindracea*, Desh.
Siliqua Nuttallii, Conr., = *Solecurtus N.*, Conr., = *Solecurtus maximus*, Gld., non Wood, = *Solen splendens*, Chenu.
Siliqua lucida, Conr., = *Solecurtus l.*, Conr., = *Solecurtus radiatus*, Gld., non Linn.

In his "Synopsis of the Genera *Parapholas* and *Penitella*," from the same source, p. 335, are given as synonyms—

Parapholas Californica, Conr., =*Pholas C.*, Conr., =*Pholas Janelli*, Desh.
Penitella Conradi, Val., =*Pholas penita*, Conr., =*Pholas concamerata*, Desh.
Penitella melanura, Sby., =*Penitella Wilsoni*, Conr. (not *Parapholas bisulcata*).

In the elaborate but somewhat intricate "Monograph of the Order *Pholadacea*," &c., by G. W. Tryon, jun., Philadelphia, 1862, the following species are quoted from the West Coast, and form the conclusion of the marine shells hitherto described, so far as known to the writer:—

Page.
49. *Rocellaria* [*Gastrochæna*] *ovata*, Sby. Panama, W. I., and Charleston, *Stimpson*. "Not the slightest difference between the Pacific and Atlantic specimens."
74. *Pholas* (*Cyrtopleura*) *truncata*, Say. Massachusetts; S. Carolina; Payta, Peru, *Ruschenberger*; Chili.
77. *Dactylina* (*Gitocentrum*) *Chiloënsis*, King, 1832,=*Ph. laqueata*, Sby., 1849. Peru, Chili [Panama, *Jewett*]. Scarcely differs from *D. Campechensis*,= *Ph. oblongata*, Say, =*Ph. Candeana*, D'Orb.; Southern U. S., W. I.
82. *Navea subglobosa*, Gray, Ann. N. H. 1851, vol. viii. p. 385. California. ["In a hole in a shell. Cabinet Gray." Neither shell nor authority stated.]
85. *Pholadidea* (*Hatasia*) *melanura*, Sby. Lower California,=*Penitella Wilsonii*, Conr., J. A. N. Sc. Ph., fig. 4 (non 5). "This error in figuring led Dr. Gray to misunderstand both the species and Conrad's idea of the genus *Penitella*." [*Vide* Brit. Assoc. Rep. 1856, p. 265.]
87. *Penitella penita*. [Mr. Tryon erroneously quotes (*Netastoma*) *Darwinii*, as well as *Ph. cornea*, as synonyms.]
88. *Jouannetia* (*Pholadopsis*) *pectinata*, Conr.,=*Triomphalia pulcherrima*, Sby. "California" [no authority], W. Columbia.
127. "*Pholas retifer*, Mörch, Mal. Blätt. vii. 177, Dec. 1860. One broken right valve. *Hab.* Real Llejos." =*Dactylina* (*Gitocentrum*) *Chiloënsis*, King [teste Tryon].

112. The following Table contains a complete list of all the Molluscs which have been identified, from Vancouver Island to S. Diego, arranged so as to show at the same time their habitat, and the principal collectors who have obtained them. The species in the first column were obtained by Prof. Nuttall; in the second, by Col. Jewett. The third column (marked B.A.) contains the species tabulated from other sources in the First Report. Those to the right of the double column are the fresh explorations recorded in this Supplementary Report. The fourth column contains the shells brought by the Pacific Railroad Expeditions, as well as the species sent to the officers of the Smithsonian Institution by the Rev. J. Rowell and their various correspondents. The fifth column ('Ken.') contains the species of the American, and the sixth ('Lord') of the British North Pacific Boundary Survey. The seventh records the collections of Mr. Swan and his Indian children; the last, those of Dr. Cooper in the Californian Geological Survey. As a large proportion of the species are as yet unknown, and the diagnoses will be found scattered in various periodicals, some of which are rarely accessible in this country, it has been judged needful to add a few words of description, with references to well-known books. By this means the student will have before him a compact handbook of the fauna, and will distinguish at a glance the range of localities, and the amount of authority for each. For the full synonymy, the previous pages of the two Reports must be consulted.

Results of the Explorations in the Vancouver and Californian Province. 1864.
(*Omitting the doubtfully located and undetermined species.*)

The letters stand fo the localities in which the shells were collected, as follows:—

V. Vancouver Island, Straits of S. Juan de Fuca, and adjoining shores of Washington Territory, formerly known as 'Oregon.'
P. Puget's Sound and the neighbourhood.
O. Oregon; and the region on each side of the Columbia River.
C. California; or the district north of the peninsula, generally.
L. Peninsula of Lower California.
F. Neighbourhood of S. Francisco.
M. Neighbourhood of Monterey.
B. „ Sta. Barbara.
D. The region between S. Diego and S. Pedro.
I. The islands: in the 4th column, generally the Farallones; in the last, the Sta. Barbara group.
H. Species obtained from the backs of Haliotids; locality unknown; probably Lower California.
fr. Fragments only.
fos. Only found fossil.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
Defrancia intricata	—	—	—	—	—	—	—	D
1. Lingula albida	—	—	D	—	—	—	—	BD
2. Rhynconella psittacea	—	—	—	—	—	V	—	—
3. Terebratula unguiculus....	—	—	—	—	—	V	V	MD
4. Waldheimia pulvinata	—	—	P	—	P	—	—	—
5. —— Californica	—	—	C	—	—	—	—	I
6. —— Grayi	—	—	—	—	—	—	—	I
7. Terebratella Coreanica	—	—	—	—	—	—	V	—
8. —— caurina	—	—	P	—	P	V	V	? I
9. Xylotrya pennatifera	—	—	—	F	—	—	V	—
10. —— fimbriata	—	—	—	—	—	V	—	—

Guide to the Diagnosis of the Vancouver and Californian Shells.

Class POLYZOA. Family *Discoporidæ.*

Defrancia intricata, Busk. Maz. Cat. no. 13. From Southern fauna The remaining species in this class have not yet been determined.

Class PALLIOBRANCHIATA. Family *Lingulidæ.*

1. *Lingula albida,* Hds. Voy. Sulph.; Rve., Hanl., Davidson et auct. 20 fm. c. *Cp.*

Family *Rhynconellidæ.*

2. *Rhynconella psittacea,* Linn. auct. E. & W. Atlantic: circumpolar.

Family *Terebratulidæ.*

3. *Terebratula unguiculus,* n. s. Like *Terebratella caput serpentis* in size, shape, and sculpture; but loop incomplete in adult, as in *T. vitrea.* 6–20 fm. not r. *Cp.*
4. *Waldheimia pulvinata,* Gld. E.E. Smooth, subglobular, ashy. 80 fm., living, *Cp.*, CI.
5. ? *Waldheimia Californica,* Koch, non auct. Colour ashy. Intermediate between *Coreanica* and *globosa,* Lam., Rve. (which is *Californica,* auct. non Koch).
6. *Waldheimia Grayi,* Davidson. Very transverse, reddish, deeply ribbed.
7. *Terebratella Coreanica,* Ad. & Rve. Voy. Samarang. Size of *globosa*; reddish. =*miniata,* Gld. Jun. ?=*frontalis,* Midd., Asia.
8. *Terebratella caurina,* Gld. E.E. Like *dorsata*; subtriangular, ashy, with strong or faint ribs.

Class LAMELLIBRANCHIATA. Family *Teredidæ.*

9. *Xylotrya pennatifera,* Blainv. Ann. Nat. Hist. 1860, p. 126.
10. *Xylotrya fimbriata,* Jeffr. in Ann. Nat. Hist. 1860, p. 126; =*palmulata,* Fbs. & Hanl., non Lam. Phil.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
11. Zirphæa crispata	—	—	—	—	P	—	? V	D *fr.*
12. Pholadidea penita	B	B	C	VOFMB	P	—	V	MD
13. —— ovoidea	—	D	D	H	—	—	—	M
14. Netastoma Darwinii	—	—	M	—	—	V	—	C
15. Martesia intercalata	—	—	—	I	—	—	—	—
16. Parapholas Californica....	B	—	C	—	—	—	—	D
17. Saxicava pholadis	—	M	CL	MCH	P	V	V	D
18. Glycimeris generosa	—	—	P	PF	—	—	—	D
19. Mya truncata............	—	—	P	—	P	—	—	—
20. Platyodon cancellatus	B	—	C	FD	—	—	—	FDI
21. Cryptomya Californica ..	B	B	C	F	P	—	V	D
22. Schizothærus Nuttalli	—	B	C	OFM	P	—	V	D
23. Darina declivis	—	—	—	—	—	V	—	—
24. Corbula luteola	—	—	—	—	—	—	—	D
25. Sphænia ovoidea	—	—	—	—	P	—	—	—
26. Neæra pectinata	—	—	—	—	P	—	—	BI

Family *Pholadidæ.*

11. *Zirphæa crispata,* Linn. auct. E. & W. Atlantic and circumpolar.
12. *Pholadidea penita,* Conr. Hanl. auct. = *concamerata,* Desh. Shape from elongate to ovoid; umbonal reflexion closely adherent.
13. *Pholadidea ovoidea,* Gld. Otia. Umbonal reflexion with anterior opening.
14. *Netastoma Darwinii,* Sby. New subgenus: valves prolonged, like duck's bill instead of cups. Surface with concentric frills. Quoted from "S. A."
15. *Martesia intercalata,* Cpr. Maz. Cat. no. 19. From Southern fauna.
16. *Parapholas Californica,* Conr. Hanl. auct. = *P. Janellii,* Desh. Very large; with layers of thin, short cups.

Family *Saxicavidæ.*

17. *Saxicava pholadis,* Linn. auct. + var. *arctica,* Linn. auct. Maz. Cat. no. 23 + var. *gastrochænoidea,* ovoid and gaping like Maz. Cat. no. 21 + var. *legumen,* Desh., elongate, cylindrical, scarcely gaping.
18. *Glycimeris generosa,* Gld. E.E. Perhaps = *Panopæa Faujasii,* S. Wood, Crag Moll.: pipes like *Saxicava.*

Family *Myadæ.*

19. *Mya truncata,* Linn. auct. = *M. præcisa,* Gld. Atlantic: circumpolar.
20. *Platyodon cancellatus,* Conr. Hanl. Pipe-ends 4-valved. Low water: common. Sold in S. Francisco market, *Cp.*
21. *Cryptomya Californica,* Conr. Outside like young *Mya*; mantle-bend nearly obsolete.

Subfamily *Lutrarinæ.*

22. *Schizothærus Nuttalli,* Conr. + *Tresus maximus,* Midd. Gray = *L. capax,* Gld. Shape from ovoid to elongate; very large and tumid; beaks swollen; hinge-sides channeled; mantle-bend joined to ventral line.
23. *Darina declivis,* n. s. Outside like *Machæra.* Cartilage-pits produced, gaping.

Family *Corbulidæ.*

24. *Corbula luteola,* n. s. Shape of young *biradiata*; small, ashy yellow. Com. *Cp.*
25. *Sphænia ovoidea,* n. s. Siphonal area small; front excurved; mantle-bend large.
26. *Neæra pectinata,* n. s. Principal ribs about 12; beak smooth. Like *sulcata.* 40–60 fm. *Cp.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
27. Clidiophora punctata	B	—	—	—	—	—	V	D
28. Kennerlia filosa	—	—	—	—	P	—	—	—
29. —— bicarinata	—	—	—	—	—	—	—	I
30. Periploma argentaria	D	—	—	—	—	—	—	D
31. Thracia curta............	B	—	—	—	P	—	V	—
32. Lyonsia Californica	B	B	PC	—	P	—	V	MD
33. —— Entodesma saxicola..	—	—	—	I	—	V	V	—
34. —— —— inflata	—	—	L	—	—	—	—	D
35. Mytilimeria Nuttalli	C	—	—	D	P	—	V	—
36. Plectodon scaber	—	—	—	—	—	—	—	I
37. Solen sicarius	—	—	P	P	P	—	V	—
37 *b*.—— *v.* rosaceus	—	B	—	—	—	—	—	D
38. Solecurtus Californianus ..	B	B	C	—	—	—	—	D
39. —— subteres	B	B	C	—	—	—	—	D
40. Machæra patula	OB	F	OC	VOF	—	—	V	D
41. Sanguinolaria Nuttalli	D	—	C	L	—	—	—	DI
42. Psammobia rubroradiata ..	C	—	—	—	P	—	V	D

Family *Pandoridæ.*

27. *Clidiophora punctata*, n. g. (Type of genus=*Pandora claviculata*, P. Z. S. 1855, p. 228.) Teeth $\frac{3}{1}$, posterior long, with ossicle. Conr. sp.; like *Cl. trilineata*, but teeth more divergent; inside strongly punctate.
28. *Kennerlia filosa*, n. s. New subgenus of *Pandora* with ossicle: outer layer radiately grooved. Shell beaked.
29. *Kennerlia bicarinata*, n. s. Not beaked; 2 post. keels in convex valve. 40–60 fm. r. *Cp.* May prove=*P. bilirata*, Conr.

Family *Anatinidæ.*

30. *Periploma argentaria*, Conr. Hanl. Large, subquadrate.
31. *Thracia curta*, Conr. Hanl. Strong, subovate.
32. *Lyonsia Californica*, Conr. Hanl.+*bracteata*+*nitida*, Gld. Outline variable: often close to Atlantic *L. Floridana*: striated external layer fugacious.
33. *Entodesma saxicola*, Baird. Subgenus of *Lyonsia*: animal nestling, irregular. Close to *E. cuneata*, Ad. & Rve. Form protean: brittle, thick, lurid, with enormous ossicle. Var. *cylindracea* has the form of *Saxicava pholadis.*
34. *Entodesma inflata*, Conr.=*diaphana*, Cpr. P. Z. S. 1855, p. 228. From Southern fauna. Like *picta*, but pale, without pinch.
35. *Mytilimeria Nuttalli*, Conr. Hanl. ? Subgenus of *Lyonsia*: rounded, with spiral umbos.
36. *Plectodon scaber*, n. g., n. s. Shape of *Theora*: dorsal margins twisted-in spirally inside umbos. Lateral teeth laminated, with internal cartilage hidden, appressed. 2 r. valves, 40–60 fm. *Cp.*

Family *Solenidæ.*

37. *Solen sicarius*, Gld. Otia. Nearly straight, rather short, truncated.
37 *b*. *Solen* ? var. *rosaceus.* Straight, narrower, longer, smaller; glossy, rosy.

Family *Solecurtidæ.*

38. *Solecurtus Californianus*, Conr. Hanl. May be a var. of the Peruvian ?*Dombeyi.* Yellowish ash, with ventral parallel grooves. A ?var. without grooves closely resembles *gibbus.*
39. *Solecurtus subteres*, Conr. Hanl. Small, compact, with violet rays.
40. *Machæra patula*, Dixon=*S. maximus*, Wood=*grandis*, Gmel.=*Siliqua Nuttalli* ?+*lucida*, Conr. (var. jun.) Asia.

Family *Tellinidæ.*

41. *Sanguinolaria Nuttalli*, Conr. Hanl.=*Psammobia decora*, Hds. Flat, rounded.
42. *Psammobia rubro-radiata*, Nutt. Large: shape of *vespertina*: rayed with lilac.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
43. Macoma secta	D	D	C	MIL	—	—	—	D
43 b.—— v. edulis	O	—	—	PO	P	—	—	—
44. —— indentata	—	—	—	—	—	—	—	D
45. —— yoldiformis	—	—	—	—	P	—	V	D
46. —— nasuta	OD	D	OC	VPOF	P	V	V	MD
47. —— inquinata	—	—	O	O	P	—	V	F
47 b.—— ? edentula	—	—	—	—	—	—	V	—
48. —— v. expansa..........	—	—	—	—	P	—	—	—
49. —— inconspicua	O	—	—	OF	P	V	V	FM
50. Angulus modestus	—	—	—	—	P	—	—	—
50b.—— —— obtusus	—	—	—	D	P	—	V	D
51. —— variegatus..........	—	—	—	—	—	—	V	MI
52. —— Gouldii	—	—	—	DL	—	—	—	D
53. —— Mæra salmonea	—	—	—	F	—	—	V	M
54. Tellina Bodegensis	—	—	OF	O	—	—	V	D
55. —— Arcopagia lamellata..	—	—	—	—	—	—	—	D
56. Œdalia subdiaphana......	—	—	—	D	—	—	—	—
57. Cooperella scintillæformis .	—	—	—	—	—	—	—	DI
58. Lutricola alba	B	B	C	—	—	—	—	DI

43. *Macoma secta,* Conr. Hanl. Large, flat, rounded, glossy; winged behind ligament.
43 *b.* *Macoma* var. *edulis,* Nutt. Northern form, less transverse; texture dull.
44. *Macoma indentata,* n. s. Like *secta,* jun., but beaked, indented, and ventrally produced.
45. *Macoma yoldiformis,* n. s. Small, white, glossy, very transverse; ligament-area scooped-out.
46. *Macoma nasuta,* Conr. auct. + *tersa,* Gld. Large, beaked, twisted; mantle-bend touching opposite scar in one valve. From Kamtschatka to S. Diego. Cape Lady Franklin, 76°, *Belcher,* 1826. 3 ft., mud, between tide-marks, *Lord.*
47. *Macoma inquinata,* Desh. P. Z. S. 1854, p. 357. Like degraded *nasuta*; mantle-bend a little separated from scar in both valves.
47 *b.* *Macoma ?edentula,* Brod. & Sby. jun.; or an abnormal var. of *inquinata.*
48. *Macoma* ?var. *expansa.* Scars like *lata* and *calcarea* in Mus. Cum., but teeth not bifid, very thin, glossy. Scarcely differs from *lata,* Desh. in B. M. Greenland.
49. *Macoma inconspicua,* Br. & Sby. = *Sang. Californiana,* Conr. Probably = "*Fabricii* = *fragilis,* Fabr." in Mus. Cum. Like thin, flat *solidula*: pink; var. large, white. 8–15 fm. *Lyall.*
50. *Angulus modestus,* n. s. (Subg. of *Tellina.*) Like *tener,* Say; but with callus between mantle-bend and scar. White.
50 *b.* *Angulus* ?var. *obtusus.* Inside like *modestus*; but beaks obtuse.
51. *Angulus variegatus,* n. s. Shape of *obtusus*: no callus; rayed with pink and yellow. 20–60 fm. r. *Cp.*
52. *Angulus Gouldii,* Hanl. MS. in Mus. Cum. Small, white; ant. ventr. side swollen.
53. *Mæra salmonea,* n. s. (Scarcely differs from *Angulus.*) Small, subquadrate, glossy, salmon-tinted. Beach–20 fm. *Cp.*
54. *Tellina Bodegensis,* Hinds, Voy. Sulph. Large, strong, transverse, with concentric grooves.
55. *Arcopagia lamellata,* Maz. Cat. no. 58. One fine pair in shell washings.
56. *Œdalia subdiaphana,* n. g., n. s. Thin, swollen, shape of *Kellia,* ligament surrounding beaks: hinge with 5 bifid teeth (3-2); no laterals; large mantle-bend.
57. *Cooperella scintillæformis,* n. s. New subgenus of *Œdalia.* Cartilage semi-internal: only 1 tooth bifid.
58. *Lutricola alta,* Conr. (*Tellina*). For this group (= *Capsa,* "Bosc," Add. non Lam.), scarcely agreeing with either *Macoma* or *Scrobicularia,* Blainville's

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
59. Semele decisa	D	D	C	—	—	—	—	D
60. —— rupium	—	—	—	—	—	—	—	I
61. —— rubrolineata	D	D	—	—	—	—	V	—
62. —— pulchra	—	—	—	D	—	—	—	D
63. —— incongrua	—	—	—	—	—	—	—	I
64. Cumingia Californica	B	—	—	—	—	—	—	DI
65. Donax Californicus	B	D	C	DL	—	—	—	D
66. —— flexuosus	—	B	—	—	—	—	—	—
67. —— navicula	—	—	—	D	—	—	—	D
68. Heterodonax bimaculatus	D	—	—	L	—	—	—	D
69. Standella Californica	B	B	—	F	—	—	V *fr.*	D
69 *b.* —— nasuta	—	—	C	—	—	—	—	? D
70. —— planulata	B	—	—	—	—	—	—	D
71. —— falcata	—	—	P	—	P	—	V	—
72. Raëta undulata	—	—	L	—	—	—	—	D
73. Clementia subdiaphana ..	—	—	—	—	P	V	—	—
74. Amiantis callosa	B	B	C	L	—	—	—	D
75. Pachydesma crassatelloides	BD	B	C	FM	—	—	V *fr.*	D
76. Psephis tantilla	—	B	—	O	P	V	V	I

synonymic name may be revived in restricted sense. Species=*biangulata*, P. Z. S. 1855, p. 230.

59. *Semele decisa*, Conr. auct. Large, rough, like Peruvian *corrugata*, but truncated.
60. *Semele rupium*, Sby. Smaller, rough, swollen; with smaller mantle-bend. Galapagos. Not r. *Cp.*
61. *Semele rubrolineata*, (? Conr.). Flattened, same shape, with faint sculpture each way, and pink rays. [Conrad's lost shell may be young *decisa*.]
62. *Semele pulchra*, Sby. Transverse, crowded concentric sculpture, with radiating lines at sides. Southern fauna.
63. *Semele incongrua*, n. s. Like *pulchra*, with concentric sculpture differing in r. and l. valves: fine radiating striæ all over. 40–60 fm. c. *Cp.*
64. *Cumingia Californica*, Conr. auct. Maz. Cat. no. 44.
65. *Donax Californicus*, Conr. (non Desh.) = *obesus*, Gld. (non Desh.). Smooth, stumpy: outline and colour variable.
66. *Donax flexuosus*, Gld. Like *punctostriata* jun. with stronger keel, and no punctures.
67. *Donax navicula*, Sby. Maz. Cat. no. 77. From Southern fauna.
68. *Heterodonax bimaculatus*. Broad var., generally violet, = *Psammobia Pacifica*, Conr. = *Tellina vicina*, C. B. Ad. Cape St. Lucas, Acapulco, W. Indies.

Family *Mactridæ*.

69. *Standella Californica*, Conr. (non Desh.). Large, shaped like *Schiz. Nuttalli*, but beaks narrow. Mantle-bend separate from ventral line.
69 *b.* *Standella* ? var. *nasuta*, Gld. (suppressed). Revived for young shells between *Californica* and *planulata*, till more is known.
70. *Standella planulata*, Conr. Nearly as large; shape approaching *Mactrella exoleta*.
71. *Standella falcata*, Gld. Otia. Shape like *planulata*, but flatter.
72. *Raëta undulata*, Gld. Otia. Like the Atlantic *R. canaliculata*, but reversed. Rare at S. Pedro, *Cp.*

Family *Veneridæ*.

73. ? *Clementia subdiaphana*, n. s. Hinge normal, very thin, ashy.
74. *Amiantis callosa*, Conr. (not auct.). Subgenus of *Callista*: hinge-plate roughened as in *Mercenaria*: mantle-bend as in *Dosinia*. L. w. com. *Cp.*
75. *Pachydesma crassatelloides*, Conr. auct. Subgenus of *Trigona*, with fewer teeth: jun. = *stultorum*, Gray.
76. *Psephis tantilla*, Gld. Otia. Subgenus of *Venus*: animal ovoviviparous. Teeth elongate, approaching *Pachydesma*. Small, with purple spot. 12–20 fm. c. *Cp.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
77. Psephis Lordi	—	—	—	—	P	V	V	I
78. —— salmonea	—	—	—	—	—	—	—	DI
79. —— tellimyalis	—	—	—	H	—	—	—	—
80. Venus Kennerleyi........	—	—	—	—	P	—	V	—
81. Chione succincta	BD	D	C	—	—	—	—	D
82. —— excavata	D	—	—	—	—	—	—	—
83. —— simillima	D	D	C	L	—	—	—	D
84. —— fluctifraga..........	D	D	C	D	—	—	—	D
85. Tapes tenerrima	—	B	F	F	—	—	V	D
86. —— laciniata	—	—	M	D	—	—	—	D
87. —— staminea	DC	F	F	FD	—	—	—	FD
87 *b.* —— *var.* Petitii........	—	—	C	VPOM	P	V	V	FM
87 *c.* —— *var.* ruderata	—	—	—	—	—	—	V	—
88. Saxidomus aratus........	—	—	—	F	—	—	—	FD
89. —— Nuttallii	D	D	C	—	—	—	—	FD
90. —— squalidus	—	F	O	VPOF	P	V	V	—
91. —— brevisiphonatus	—	—	—	—	—	V	—	—
92. Rupellaria lamellifera	D	M	C	D	—	—	—	M
93. Petricola carditoides	BD	MB	C	F	P	—	V	M
94. Chama exogyra..........	BD	—	C	LH	—	—	—	D
95. —— pellucida	B	B	C	MD	—	—	—	FMD

77. *Psephis Lordi*, Baird, P. Z. S. 1863. Teeth normal: pure white. 20–40 fm. c. *Cp.*
78. *Psephis salmonea*, n. s. Very small, rounded, teeth elongate: salmon-coloured. 30–40 fm. r. *Cp.*
79. *Psephis tellimyalis*, n. s. Shape of *Tellimya*: central tooth minute; outside teeth long.
80. *Venus Kennerleyi*, Rve. Large, transverse, flattened, ashy: strong conc. ribs. Young like *astartea*, Midd. (not *fluctuata*, Gld.).
81. *Chione succincta*, Val. = *Californiensis*, Brod. = *Nuttalli*, Conr. Conc. ribs smooth.
82. *Chione excavata*, Cpr. P. Z. S. 1856, p. 216. Scarcely differs from *cancellata*. Possibly exotic.
83. *Chione simillima*, Sby. Finely sculptured each way.
84. *Chione fluctifraga*, Sby. + *callosa*, Sby. Like *Stutchburyi*: swollen, irregular.
85. *Tapes tenerrima*, Cpr. P. Z. S. 1856, p. 200, (jun.) = *V. rigida*, Gld. pars, f. 538. Very large, thin, flat; long pointed sinus.
86. *Tapes laciniata*, n. s. Large, swollen, brittle, ashen; sculpture pectinated.
87. *Tapes staminea*, Conr. Strong, shape of *decussata*; sculpture close; yellowish. Var. *diversa*, Sby. = *mundulus*, Rve. More swollen, clouded with chocolate. Var. *Petitii*, Desh. = *rigida*, Gld. pars. Dead white, sculpture strong or faint, open or close. 2 ft. deep in mud, between tides, *Lord.* Var. *tumida*, Sby. Very swollen. Var. *orbella*, rounded, globose. Var. *ruderata*, Desh. Concentric sculpture laminated.
88. *Saxidomus aratus*, Gld. Otia. Very large, oval, with regular concentric ridges.
89. *Saxidomus Nuttallii*, Conr. auct. Transverse, subquadrate, irregularly grooved.
90. *Saxidomus squalidus*, Desh. Large, variable outline, broader, scarcely sculptured.
91. *Saxidomus brevisiphonatus*, n. s. Smaller, *Callista*-shaped; close, faint concentric lines over distant waves; mantle-bend very small.

Family *Petricolidæ*.

92. *Rupellaria lamellifera*, Conr. = *Cordieri*, Desh. With large concentric laminæ. No radiations.
93. *Petricola carditoides*, Conr. + *Californica*, Conr. + *cylindracea*, Desh. + *arcuata*, Desh. + *gibba*, Midd. Of various aspects, like *Saxicava*. Normally shaped like *Cypricardia*, with fine sculpture like *Naranio*.

Family *Chamidæ*.

94. *Chama exogyra*, Conr. Reversed; texture opaque; rudely frilled.
95. *Chama pellucida*, Sby. Dextral, texture porcellanous, rosy; closely frilled. S.A.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
96. Chama spinosa	—	—	—	—	—	—	—	? D
97. Cardium corbis	OB	—	OC	VPOF	P	V	V	F
98. —— quadragenarium	B	—	—	D	—	—	—	D
99. —— *var.* blandum	—	—	P	—	P	V	V	—
100. —— *var.* centifilosum	—	—	—	—	—	—	—	I
101. Hemicardium biangulatum	—	—	—	—	—	—	—	I
102. Serripes Grœnlandicus	—	—	—	—	P	—	—	—
103. Liocardium elatum	—	—	—	—	—	—	—	D
104. —— substriatum	D	—	C	—	—	—	—	D
105. Astarte compacta	—	—	—	—	P	—	—	—
106. —— Esquimalti	—	—	—	—	—	V	—	—
107. —— fluctuata	—	—	—	—	—	—	—	I
108. Miodon prolongatus	—	—	—	—	—	—	V	? C
109. Venericardia borealis	—	—	—	—	—	V	—	I
109 *b*. —— *var.* ventricosa	—	B *fs.*	P	—	P	—	—	I
110. Lazaria subquadrata	—	B	—	II	—	—	V	MDI
111. Lucina Nuttallii	D	—	—	—	—	—	—	I
112. —— Californica	D	B	—	D	—	—	—	I
113. —— bella	D	—	—	—	—	—	—	—
114. —— tenuisculpta	—	—	—	—	P	—	—	DI

96. *Chama spinosa*, Sby. Ridges broken into close short spines. Maz. Cat. no. 122.

Family *Cardiadæ.*

97. *Cardium corbis*, Mart.=*Nuttalli*+*Californianum*, Conr. Large, earthen, rather nodulous; posterior margin strongly indented by 2 first ribs. Asia. 8–15 fm. *Lyall.* Jun. in stomach of starfish, 12 fm. *Lord.*

98. *Cardium quadragenarium*, Conr.=*luteolabrum* (=*xanthocheilum*), Gld. Very large; 40 ribs, with aculeate spines.

99. *Cardium* var. *blandum*, Gld. Otia. Delicate form of the Asiatic *pseudofossile*, Rve.=*Californiense*, Desh. Transverse; close, flat ribs; margin regular. 8–15 fm. *Lyall.*

100. *Cardium* var. *centifilosum*. Probably=*modestum*, Ad. & Rve.; but rounder, ribs sharper and more distant. Belongs to subg. *Fulvia*, Gray. 30–40 fm. *Cp.*

101. *Hemicardium biangulatum*, Sby. Southern fauna. 10–20 fm. living. *Cp.*

102. *Serripes Grœnlandicus*, Chem. auct. Boreal. Rounder than *S. Laperousii.*

103. *Liocardium elatum*, Sby. Maz. Cat. no. 124. Gulf fauna. Very large, *Cp.*

104. *Liocardium substriatum*, Conr.=*cruentatum*, Gld. Almost identical with the Peruvian *Elenense.*

Family *Astartidæ.*

105. *Astarte compacta*, n. s. Like *compressa*, but closer; dorsal margins straight, at right angles.

106. *Astarte Esquimalti*, Baird, P. Z. S. 1863, p. 70. Subtrigonal; ribs irregular.

107. ?*Astarte fluctuata*, n. s. Very close to *Omalii*, jun. of Coralline Crag. 2 right v. 30–40 fm. *Cp.*

108. *Miodon prolongatus*, n. g., n. s. Outside Lucinoid; hinge and scars nearer to *Venericardia*. Congeneric with *Astarte orbicularis*, J. Sby. Min. Conch. pl. 444. f. 2, 3 (non ejusdem, pl. 520. f. 2). G. Oolite; and with the Crag *Cardita corbis.*

109. *Venericardia borealis*, Conr. N. Atlantic, from Miocene. 120 fm. Cat. Is. *Cp.*

109 *b*. *Venericardia* var. *ventricosa*, Gld. Small, swollen. 30–40 fm. *Cp.*

110. *Lazaria subquadrata*, n. s. Hinge of *Lazaria*: outside like *Cardita variegata*, jun.

Family *Lucinidæ.*

111. *Lucina Nuttallii*, Conr. Hanl. Like *muricata*, with more delicate sculpture.

112. *Lucina Californica*, Conr. Dosinoid, with waved lunule. Jun.?=*L. Artemidis*, P. Z. S. 1856, p. 201.

113. *Lucina bella*, Conr. Shell not known: may be =*pectinata*, Maz. Cat. no. 142.

114. *Lucina tenuisculpta*, n. s. Like *Mazatlanica*, Cat. no. 144, more convex, with finer sculpture. 4 fm. living, *Cp.* The island var. is intermediate. 120 fm. dead, *Cp.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
115. Lucina borealis	—	—	—	—	—	—	—	I
116. Cryptodon flexuosus	—	—	—	—	—	—	—	I
117. —— serricatus	—	—	—	—	P	V	—	I?
118. Diplodonta orbella	B	B	C	D	—	—	V	D
119. Kellia Laperousii	—	—	C	M	P	—	V	—
119 *b.* —— var. Chironii	—	—	—	—	—	—	V	D
120. —— rotundata	—	—	—	M	—	—	—	—
121. —— suborbicularis......	—	—	—	H	P	—	—	DI
122. Lasea rubra............	—	—	—	—	P	—	—	I
123. Pythina rugifera........	—	—	—	—	P	—	—	—
124. Lepton meroëum	—	—	—	—	—	—	—	D
125. Tellimya tumida........	—	—	—	—	P	—	V	D
126. Pristes oblongus	—	—	—	—	—	—	—	D
127. Mytilus Californianus....	MD	C	C	PFC	P	V	V	FDI
128. —— edulis	C	C	C	PC	P	V	V	F
128 *b.* —— *var.* glomeratus ..	—	—	F	—	—	—	—	—
129. Septifer bifurcatus	? C	—	F	FH	—	—	—	DI
130. Modiola capax	B	C	C	—	—	—	—	D
131. —— modiolus..........	—	M	P	VH	P	V	V	M
132. —— fornicata..........	—	B	—	M	—	—	—	—
133. —— recta	B	B	C	—	—	—	—	D

115. *Lucina borealis*, Linn. auct. + *acutilineata*, Conr. Widely diffused, from Coralline Crag. Philippines, teste Cuming. 30–120 fm. *Cp.*
116. *Cryptodon flexuosus*, Mont. auct. Atlantic, circumpolar. Cat. Is. 120 fm. *Cp.*
117. *Cryptodon serricatus*, n. s. Small, circular, flat; epidermis silken. ? Cat. Is. *Cp.* 120 fm.

Family *Diplodontidæ.*

118. *Diplodonta orbella*, Gld. Otia. = (*Mysia*) *Sphærella tumida*, Conr.

Family *Kelliadæ.*

119. *Kellia Laperousii*, Desh. Woodw. Typically large, strong, transverse.
119 *b.* *Kellia* var. *Chironii.* Thinner, less transverse, margins rounded.
120. *Kellia rotundata*, n. s. Larger, flatter, and less pearly than *suborbicularis.* Margin circular.
121. *Kellia suborbicularis*, Mont. auct. Maz. Cat. no. 153. N. Atlantic: W. Mexico. Exactly accords with British sp. 30–40 fm. *Cp.*
122. *Lasea rubra*, Mont. auct. Maz. Cat. no. 154. N. Atlantic: W. Mexico. Exactly accords with British sp.
123. *Pythina rugifera*, n. s. Large, thin, slightly indented; teeth minute; epidermis shaggy.
124. *Lepton meroëum*, n. s. Small, shaped like *Sunapta.*
125. *Tellimya tumida*, n. s. Between *bidentata* and *substriata*: ossicle minute.
126. *Pristes oblongus*, n. g., n. s. Like *Tellimya*, with long marginal teeth, serrated near hinge.

Family *Mytilidæ.*

127. *Mytilus Californianus*, Conr. 9 in. long: stained with sienna: obsoletely ribbed.
128. *Mytilus edulis*, Linn. auct. = *trossulus*, Gld. Abundant on whole coast, with the usual Atlantic vars. Between tide-marks, *Lord*: also brown var. on floating stick.
128 *b.* *Mytilus* ? var. *glomeratus*, Gld. Otia. Short, stumpy, solid, crowded.
129. *Septifer bifurcatus*, Rve. Outside like *Mytilus b.* Conr. from Sandw. Is.
130. *Modiola capax*, Conr. Maz. Cat. no. 170. From Southern fauna.
131. *Modiola modiolus*, Linn. auct. Circumboreal. 8–15 fm. jun. *Lyall.*
132. *Modiola fornicata*, n. s. Short, swollen, like large *M. marmorata*; but smooth, not crenated.
133. *Modiola recta*, Conr. 6 in. long, thin, narrow, rhomboidal. Chaff-like hairs over glossy epidermis.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
133 *b*. Modiola var. flabellata. .	—	—	V	VP	P	—	V	—
134. Adula falcata	—	M	M	FM	—	—	—	D
135. —— stylina.	—	—	—	OFM	—	—	V	—
136. Lithophagus plumula. . . .	—	—	—	M	—	—	—	D
137. —— attenuatus	—	—	L	H	—	—	—	—
138. Modiolaria lævigata	—	—	—	—	P	V	V	—
139. —— marmorata	—	—	P	—	P	—	—	—
140. Crenella decussata	—	—	—	—	—	—	—	I
141. Arca multicostata	—	—	—	D	—	—	—	—
142. Barbatia gradata	—	—	—	—	—	—	—	D
143. Axinæa intermedia	—	—	—	—	—	—	—	MDI
144. —— *var.* subobsoleta	—	—	—	ODI	—	—	V	—
145. Nucula tenuis	—	—	—	—	P	—	—	—
146. —— Acila castrensis	—	—	—	—	P	V	—	I
147. Leda cælata	—	B	F	—	—	—	—	MD
148. —— cuneata	—	—	—	—	—	—	—	MDI
149. —— minuta.	—	—	—	—	P	—	—	—
150. —— fossa	—	—	—	—	P	V	—	—
151. —— hamata	—	—	—	—	—	—	—	BI

133 *b*. *Modiola* var. *flabellata*, Gld. Northern form, somewhat broader.

134. *Adula falcata*, Gld. Otia. Subgenus enlarged to include species intermediate between *Modiola* and *Lithophagus*: shape of latter, byssiferous like former, nestling in crypts. Sp. = *Gruneri*, Phil. MS. Shape not always falcate: chestnut, rugose.

135. *Adula stylina*, n. s. Shorter, broader; epidermis brown, glossy.

136. *Lithophagus plumula*, Hanl. Maz. Cat. no. 175. From Southern fauna.

137. *Lithophagus attenuatus*, Desh. Maz. Cat. no. 173. From Southern fauna.

138. *Modiolaria lævigata*, Gray. Exactly accords with Atlantic specimens. Circumboreal.

139. *Modiolaria marmorata*, Fbs. & Hanl. Exactly accords with Atlantic specimens. Circumboreal.

140. *Crenella decussata*, Mont. Exactly accords with Atlantic specimens. Circumboreal. 10–40 fm. not r. *Cp.*

Family *Arcadæ.*

141. *Arca multicostata*, Sby. Maz. Cat. no. 181. } From Southern fauna.
142. *Barbatia gradata*, Sby. Maz. Cat. no. 194. }

143. *Axinæa intermedia*, Brod. = *Barbarensis*, Conr. fossil. Closely accords with the Peruvian specimens. 40–60 fm. *Cp.*

144. *Axinæa* (? *septentrionalis*, Midd. var.) *subobsoleta*. Sculpture much fainter than in Midd.'s fig.

Family *Nuculidæ.*

145. *Nucula tenuis*, Mont. auct. Agrees with var. *lucida*, Gld. Circumboreal.

146. *Acila castrensis*, Hds. Sulph. + *Lyalli*, Baird. Subg. of *Nucula* with divaricate sculpture; only known in Crag and N. Pacific. 40–60 fm. *Cp.*

147. *Leda cælata*, Hds. Sulph. Swollen, strongly sculptured: teeth very numerous. 10–60 fm. *Cp.*

148. *Leda cuneata*, Sby. D'Orb. teste Hanl. (Scarcely differs from *commutata*, Phil. in Mus. Cum.) = *inornata*, A. Ad. Chili. 0–60 fm. *Cp.*

149. *Leda minuta*, O. Fabr. teste Hanl. Circumboreal. Agrees with Norwegian specimens of "*caudata*, Don." teste M'Andr.

150. *Leda fossa*, Baird, P. Z. S. 1863, p. 71. Between *minuta* and *pernula*. Sculpture nearly obsolete.

151. *Leda hamata*, n. s. Like *Steenstrupi* and *pernuloides*, but very hooked, sculpture strong. 20–60 fm. c. *Cp.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
152. Yoldia lanceolata	—	—	—	—	P	—	—	—
153. —— amygdala	—	—	—	—	P	—	—	—
154. Verticordia ornata	—	—	—	—	—	—	—	BI
155. Bryophila setosa	—	—	—	H	—	—	—	? C
156. Lima orientalis	—	—	—	—	—	—	—	MDI
157. Limatula subauriculata ..	—	—	—	—	—	—	—	DI
158. Pecten hastatus	—	B	P	—	P	V	V	M
159. —— ?*var.* Hindsii	—	—	P	—	P	V	V	—
160. —— *var.* æquisulcatus ..	—	B	—	D	—	—	—	BD
161. —— paucicostatus	—	B	—	—	—	—	—	I
162. —— ?*var.* latiauritus	BD	D	C	D	—	—	—	D
162*b*.—— monotimeris	BD	D	C	DL	—	—	—	D
163. Amusium caurinum	—	C jn.	O	VO	P	—	V	—
164. Janira dentata	—	—	—	—	—	—	—	MD
165. Hinnites giganteus	C	C	C	PM	P	V	V	D
166. Ostrea lurida	—	—	—	VPO	P	V	V	F

152. *Yoldia lanceolata*, J. Sby. Hanl. = *arctica*, Brod. & Sby. (Not *Adrana l.*, Lam. G. Sby.) With ant. diagonal lines.

153. *Yoldia amygdala*, var. teste Hanl. Like *lanceolata*, without posterior wing, and anterior sculpture.

Family ? *Trigoniadæ.*

154. *Verticordia ornata*, D'Orb. = *novemcostata*, Ad. & Rve. Samarang. Exactly accords with Chinese types. S. A. 20–40 fm. *Cp.*

Family *Aviculidæ.*

155. *Bryophila setosa*, n. g., n. s., Ann. N. H. 1864, p. 10. Like minute, broad *Pinna*. Animal ovoviviparous. Sta Barbara, 20 fm. *Cp.*

Family *Pectinidæ.*

156. *Lima orientalis*, Ad. & Rve., Samarang, in Mus. Cum. = *dehiscens*, Conr. fossil, teste Cp. Very close to young of *L. hians*, var. *tenera*. Beach to 20 fm. c. *Cp.*

157. *Limatula subauriculata*, Mont. Fbs. & Hanl. Circumboreal. Fossil in Crag. Islands, 40–120 fm. not r.; S. Diego, 1 valve, 4 fm. *Cp.*

158. *Pecten hastatus*, Sby. = *hericeus*, Gld. Elongated; a few principal ribs serrated; ears unequal. In var. *rubidus*, Hds. (non Mart.), the ribs are equal, not serrated.

159. *Pecten* (? var.) *Hindsii*. Broader; ribs close, small, smooth, bifurcating. Passes from *hastatus* towards *Islandicus.*

160. *Pecten æquisulcatus*, ? n. s. Thinner and flatter than *ventricosus*, with narrower ribs.

161. *Pecten paucicostatus*, ? n. s. Somewhat resembling very young *caurinus*; but ribs fewer, stronger.

162. *Pecten latiauritus*, Conr. (pars). Ribs sharply defined, with sharp concentric laminæ. Possibly an extreme form of

162*b*. *Pecten monotimeris*, Conr. = *tunica*, Phil. + *latiauritus*, Conr. pars. Passes into *Amusium.* Very slanting, thin, with faint ribs.

163. *Amusium caurinum*, Gld. E. E. Large, flat, thin, very inequivalve. Var. = *Yessoensis*, Jay. Japan.

164. *Janira dentata*, Sby. = *excavata*, Val. Ven. Like *media*. From the Gulf fauna. Beach–20 fm. *Cp.*

Family *Spondylidæ.*

165. *Hinnites giganteus*, Gray, Analyst. = *Poulsoni*, Conr. Very large, Spondyloid: ligament as in *Pedum*, strongly adherent along the ears.

Family *Ostreidæ.*

166. *Ostrea lurida*, n. s. Shape of *edulis*: texture dull, lurid, olivaceous, with purple stains. 2–3 fm. on mud flats, *Lord.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
166*b*. Ostrea *var.* laticaudata . .	—	—	—	—	—	—	—	F
166*c*.—— *var.* rufoides	—	—	—	D	—	—	—	D
166*d*.—— *var.* expansa	—	—	—	—	—	—	—	D
167. —— conchaphila . . [ma	D	—	C	L	—	—	—	D
168. Placunanomia macroschis-	—	—	OC	VF	P	V	V	F
169. Anomia lampe	—	—	C	L	—	—	—	D
170. Cavolina telemus	—	—	—	—	—	V	—	I
171. Bulla nebulosa	B	D	C	DL	—	—	—	DI
172. —— Quoyi	—	? B	—	L	—	—	—	D
173. Haminea hydatis	—	—	—	? P	P	V	—	—
174. —— vesicula	—	—	C	—	—	—	—	D
175. —— virescens	—	—	C	D	—	—	—	BD
—— Philinid	—	—	—	—	P	—	—	—
—— ?	—	—	—	—	P	—	—	—
176. Tornatella punctocælata . .	—	—	—	I	—	—	—	D
177. Tornatina culcitella	—	B	C	—	—	—	—	MI

166*b*. *Ostrea* var. *laticaudata*, Nutt. MS. Purple, winged, waved: denticles near hinge. Passes towards *palmula*, Maz. Cat. no. 214, *b*.

166*c*. *Ostrea* ? var. *rufoides*=*rufa*, Gld. (non Lam.). Passing towards *Virginica*, jun. Thin, with umbos hollowed; reddish in scar-region. Also fossil.

166*d*. *Ostrea* ? var. *expansa*. Flat, affixed to whole surface, like *Columbiensis*. Round, or winged to left, or right, or both, like *Malleus*. Also passes into

167. *Ostrea conchaphila*, Cpr. Maz. Cat. no. 214. From Southern fauna.

Family *Anomiadæ*.

168. *Placunanomia macroschisma*, Desh. Kamtschatka. Vars. = *alope* + *cepio*, Gray. Shape most variable, according to station. Sculpture often obsolete. On rock, between tides, *Lord*.

169. *Anomia lampe*, Gray, Maz. Cat. no. 219. From Southern fauna.

Class PTEROPODA. Family *Hyalæidæ*.

170. *Cavolina telemus*, Linn. = *Hyalæa tridentata*, Forsk. non Lam. Pelagic. 30–60 fm. dead, *Cp*.

[Other Pteropods were brought by the Brit. N. P. Boundary Survey, but may have been collected on the voyage: *v*. p. 607.]

Class GASTEROPODA.

Subclass Opisthobranchiata. Order Tectibranchiata.

Family *Bullidæ*.

171. *Bulla nebulosa*, Gld. Otia. Large, globular, thin. Maz. Cat. no. 225 + var. *fulminosa*, Cp.

172. *Bulla Quoyi*, Gray. Small: angular at umbilicus. Maz. Cat. no. 226. Pacific.

173. *Haminea hydatis*, Linn. auct. Exactly accords with European specimens.

174. *Haminea vesicula*, Gld. Otia. Smaller, paler, and thinner.

175. *Haminea virescens*, Sby. Gen. Var. = *cymbiformis*, Maz. Cat. no. 229.

Family ? *Philinidæ*.

Two species not yet dissected: one with internal shell like *Phanerophthalmus*.

Family *Tornatellidæ*.

176. *Tornatella punctocælata*, n. s. Small: grooved with rows of dots: pillar twisted as in *Bullina*, Add. non Gray.

Family *Cylichnidæ*.

177. *Tornatina culcitella*, Gld. Otia. Large, brownish, with faint striæ. Fold close to paries.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
177b. Tornatina cerealis	—	B	—	—	—	—	—	M
178. —— eximia	—	—	—	—	P	V	—	—
179. —— carinata	—	—	—	—	—	—	—	D
180. Cylichna ?cylindracea ..	—	B	—	—	—	—	—	MDI
180b. —— var. attonsa........	—	—	—	—	P	—	—	—
181. —— planata	—	—	—	D	—	—	—	—
182. —— inculta............	—	—	D	D	—	—	—	—
183. Volvula cylindrica	—	B	—	—	—	—	—	—
184. Neaplysia Californica	—	—	—	—	—	—	—	D
185. Navarchus inermis	—	—	—	—	—	—	—	DI
186. Pleurophyllidea Californic.	—	—	—	—	—	—	—	D
187. Doris sanguinea	—	—	—	—	—	—	—	DI
188. —— alabastrina	—	—	—	—	—	—	—	D
189. —— albopunctata	—	—	—	—	—	—	—	BI
190. —— Sandiegensis	—	—	—	—	—	—	—	DI
191. —— Montereyensis......	—	—	—	—	—	—	—	FMI
192. Triopa Catalinæ	—	—	—	—	—	—	—	I
193. Tritonia Palmeri	—	—	—	—	—	—	—	D
194. Dendronotus iris	—	—	—	—	—	—	—	B
195. Æolis Barbarensis	—	—	—	—	—	—	—	B
196. Phidiana iodinea........	—	—	—	—	—	—	—	BD
197. Flabellina opalescens	—	—	—	—	—	—	—	BDI
198. Chioræra leonina........	—	—	P	—	—	—	—	B
199. Melampus olivaceus	—	—	C	DL	—	—	—	DI
200. Pedipes liratus..........	—	—	—	L	—	—	—	D
201. Siphonaria Thersites	—	—	—	—	—	—	V	—

177b. *Tornatina cerealis*, Gld. Otia. Small, white, smooth: but probably = worn young *culcitella*.
178. *Tornatina eximia*, Baird, P. Z. S. 1863, p. 67. Size moderate: fold appressed: subrectangular.
179. *Tornatina carinata*, Maz. Cat. no. 223.
180. *Cylichna ?cylindracea*, Linn. auct. Intermediate specimens, passing into
180b. *Cylichna* var. *attonsa*, rounded off at apex.
181. *Cylichna planata*, n. s. Like *mamillata*, with apex flattened-off, and fold distinct.
182. *Cylichna inculta*, Gld. Otia.
183. *Volvula cylindrica*, n. s. Like grain of rice, pointed at one end.

Family *Aplysiadæ*.

184. *Neaplysia Californica*, Cp. Proc. Cal. Ac. 15 inches long.
185. *Navarchus inermis*, Cp. Proc. Cal. Ac. Grasses, on shore, *Cp.*

Family *Pleurophyllidiadæ*.

186. *Pleurophyllidea Californica*, Cp. Proc. Cal. Ac. Sandy flats, *Cp.*

Order Nudibranchiata.

187–198. All the new Nudibranchs are described in the Proc. Cal. Ac. *Vide anteà*, p. 609. *Vide* also Gld.'s Otia, and Esch. Zool. Atlas.

Subclass Pulmonata.

For land and freshwater species, both of Pulmonates, Rostrifers, and Bivalves, *vide posteà*, paragraphs 115–119.

Family *Auriculidæ*.

199. *Melampus olivaceus*, Cpr. Maz. Cat. no. 235.
200. *Pedipes liratus*, Binn. Proc. Ac. N. S. Phil. 1861, p. 333.

Family *Siphonariadæ*.

201. *Siphonaria Thersites*, n. s. Like *lateralis*: with strong lung-rib and obsolete sculpture.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
202. Dentalium v. Indianorum	—	—	P	—	P	—	V	MI
203. —— rectius	—	—	—	—	P	—	—	—
204. —— semipolitum	—	—	—	—	—	—	—	D
205. —— hexagonum	—	—	—	—	—	—	—	D
206. Cryptochiton Stelleri	—	C	OC	FMI	P	V	V	I
207. Katherina tunicata	—	—	O	OF	P	V	V	I
208. Tonicia lineata	—	—	C	PFM	P	V	V	—
209. —— submarmorea	—	—	—	O	—	—	V	—
210. Mopalia muscosa	M	F	P	OFMI	—	V	V	I
211. —— Wosnessenskii	—	—	C	—	—	V	—	—
212. —— Kennerleyi	—	—	—	—	P	—	V	—
212*b*. —— *var.* Swanii	—	—	—	—	—	—	V	—
213. —— Hindsii	—	—	—	F	P	—	—	—
214. —— Simpsonii	—	—	C	—	—	—	—	—
215. —— vespertina	—	—	P	F	P	—	V	—
216. —— lignosa	—	—	PM	O	P	—	V	—
217. —— acuta	M	—	—	—	—	—	—	—
218. —— sinuata	—	—	—	—	P	—	—	—
219. —— imporcata	—	—	—	—	P	—	—	—

Subclass Prosobranchiata. Order Lateribranchiata.

Family *Dentaliadæ.*

202. *Dentalium* (? *pretiosum*, Nutt. Sby. var.) *Indianorum*. Like *entalis*, with very fine posterior striæ. 20 fm. c. *Cp.*
203. *Dentalium rectius*, n. s. Long, thin, slightly curved: like *eburneum*, Singapore.
204. *Dentalium semipolitum*, Br. & Sby. ? = *hyalinum*, Phil. not Maz. Cat. no. 245. From Southern fauna.
205. *Dentalium hexagonum*, Sby. From Southern fauna.

Order Scutibranchiata. Family *Chitonidæ.*

206. *Cryptochiton Stelleri*, Midd. Very large: valves hidden. Reaches Sta Cruz, *Cp.*
207. *Katherina tunicata*, Sby. = *Douglasiæ*, Gray. Mantle smooth, black: valves partly concealed. Between tide-marks, *Lord.* Reaches Farallone Is. *Cp.*
208. *Tonicia lineata*, Wood. Closely resembling *lineolata*, Peru. Painting variable.
209. *Tonicia submarmorea*, Midd. Perhaps = *lineata*, var. without lines.
210. *Mopalia muscosa*, Gld. E. E. = *C. ornatus*, Nutt. (= *armatus*, Jay) + *consimilis*, Nutt. Highly sculptured: mantle crowded with strong hairs. Between tide-marks, *Lord.*
211. *Mopalia Wosnessenskii*, Midd. Mantle slit behind, with few hairs. Sculpture like *muscosa*.
212. *Mopalia Kennerleyi*, n. s. = *Grayi*, anteà, p. 603, nom. preoc. Sculpture fainter: olive with red: ridge angular; post. valve waved.
212*b*. *Mopalia Kennerleyi*, var. *Swanii*: red, ridge arched; less sculptured.
213. *Mopalia Hindsii*, Gray. Olive: distinctly shagreened: flat: post. valve waved.
214. *Mopalia Simpsonii*, Gray, in B.M. Col. Like *Hindsii*, with valves beaked.
215. *Mopalia vespertina*, Gld. E. E. Shape of *Hindsii*, with very faint sculpture and slight wave. Olive clouded with brown.
216. *Mopalia lignosa*, Gld. E. E. = *Merckii*, Midd. = *Montereyensis*, Cpr. P. Z. S. 1855, p. 231. Like *vespertina*, without wave: brown in streaks.
217. *Mopalia acuta*, Cpr. P. Z. S. 1855, p. 232. Subgeneric, aberrant form; with small blunt plate, instead of post. sinus, between the two principal lobes.
218. ? *Mopalia sinuata*, n. s. Small, raised sharp back, red and blue, engine-turned; post. valve deeply notched.
219. ? *Mopalia imporcata*, n. s. Pale: central areas ribbed: post. valve slightly notched. Indications of sutural pores in these two species, if confirmed, will require a new genus.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
220. Acanthopleura scabra	M	—	C	FI	P	—	—	I
221. —— fluxa	—	—	—	—	—	—	—	I
222. Ischnochiton Magdalensis	—	—	L	LM	—	—	—	DI
223. —— veredentiens	—	—	—	—	—	—	—	I
224. Lepidopleurus regularis ..	—	—	C	—	—	—	—	—
225. —— scabricostatus	—	—	—	—	—	—	—	I
226. —— pectinatus	—	—	—	—	—	—	—	I
227. —— Mertensii..........	—	—	C	M	P	—	V	—
228. Trachydermon retiporosus	—	—	—	—	P	—	—	—
229. —— interstinctus	—	—	P	—	—	—	—	—
230. —— trifidus	—	—	—	—	P	—	—	—
231. —— dentiens	—	—	P	—	—	—	—	—
231 *b*. —— pseudodentiens ..	—	—	—	—	P	V	—	D
232. —— Gothicus	—	—	—	—	—	—	—	I
233. —— Hartwegii	—	—	C	F	—	—	—	—
234. —— Nuttallii	M	—	C	M	—	—	V	I
235. —— flectens	—	—	—	M	P	V	—	D

220. *Acanthopleura scabra,* Rve. = *Californicus,* Nutt. Insertion-plates resemble *Katherina.* Valves with coarse V-shaped ribs, and projecting beaks.

221. *Acanthopleura fluxa,* n. s. Green, mottled with orange-red; not beaked; with only marginal and diagonal ribs.

222. *Ischnochiton Magdalensis,* Hds. Large, strong-valved, typical. Sculpture much fainter than in southern shells. Mantle-margin with striated scales like flattened bristles. Side plates 2- or 3-lobed. Beach–20 fm. *Cp.*

223. *Ischnochiton veredentiens,* n. s. Margin similar. Small, arched, sculptured like *Mertensii,* but with 2 rows of bosses, one of which dentates the sutures. 10–20 fm. *Cp.*

224. *Lepidopleurus regularis,* Cpr. P. Z. S. 1855, p. 232. Subgenus of *Ischnochiton*: mantle-scales Lophyroid, generally striated. Sp. arched, green, shagreened. Side lobes 2–4: eaves spongy, not projecting.

225. *Lepidopleurus scabricostatus,* n. s. Small, arched, orange: rows of prominent granules over shagreened surface. Lobes blunt, slightly rugulose, close to eaves. 8–20 fm. *Cp.*

226. *Lepidopleurus pectinatus,* n. s. Olive: strong sculpture over shagreened surface: side areas ribbed: outer margin and inner sutures pectinated. Bch. *Cp.*

227. *Lepidopleurus Mertensii,* Midd. Red: highly sculptured over smooth surface: side areas with rows of bosses. Mantle-scales smooth, rounded.

228. *Trachydermon retiporosus,* n. s. Subgenus of *Ischnochiton*: mantle-scales very small, close, smooth. Sp. like *scrobiculatus,* central pattern in network, 3–6 side ribs.

229. *Trachydermon interstinctus,* Gld. E.E. Centre minutely punctured: 6–8 blunt side ribs.

230. *Trachydermon trifidus,* n. s. Centre-punctures few, deep: 2–4 blunt ribs: side plates with 2 slits.

231. [*Trachydermon dentiens,* Gld. E.E. No shell known answering to diagnosis and figure.] The 4 following species have incisors blunt, eaves not projecting.

231 *b*. *Trachydermon pseudodentiens*=type specimen of *dentiens.* False appearance of teeth due to colour or ridges of growth. Closely granular: areas indistinct. Sinus broad, squared: eaves spongy.

232. *Trachydermon Gothicus,* n. s. Blunt parallel riblets along very arched back. Sutural lobes united at sinus: eaves not spongy. 8–20 fm. *Cp.*

233. *Trachydermon Hartwegii,* Cpr. P. Z. S. 1855, p. 231. Large, arched. Inside callous, without rows of punctures to slits: eaves spongy.

234. *Trachydermon Nuttallii,* Cpr. P. Z. S. 1855, p. 231. Large, plain, flat. Incisors slightly rugulose: eaves spongy.

235. *Trachydermon flectens,* n. s. Mantle-margin scarcely granular. Rosy, very small, scarcely sculptured: valves beaked and waved as in *M. Simpsonii*: eaves and incisors normal.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
236. Leptochiton nexus	—	—	—	—	—	—	—	I
237. Acanthochites avicula ..	—	—	—	—	—	—	—	I
238. Nacella instabilis........	—	—	P	—	—	V	V	—
239. —— incessa............	—	B	D	D	—	—	—	MD
240. —— subspiralis	—	—	—	—	—	—	—	I
241. —— depicta............	—	—	D	—	—	—	—	D
242. —— paleacea	—	B	—	—	—	—	—	—
242 *b.* —— *var.* triangularis ..	—	—	—	—	—	—	—	M
243. Acmæa patina	C	C	C	VFM	P	V	V	FMBI
244. —— pelta	C	C	C	VFM	P	V	V	FMBI
244 *b.* —— *var.* Asmi........	—	B	—	I	—	—	—	M
245. —— persona	O	C	C	VF	P	V	V	FBDI
246. —— scabra	D	C	C	DIH	—	—	—	MDI
247. —— spectrum	D	C	C	FDIH	—	—	—	MBD
248. —— rosacea	—	B	—	—	—	—	—	MD
249. Lottia gigantea	—	—	C	FMIL	—	—	—	MBDI
250. Scurria mitra	M	C	PC	VPF	P	V	V	MI
250 *b.* —— ?*var.* funiculata ..	—	—	—	—	—	—	—	M

236. *Leptochiton nexus*, n. s. Like *asellus*: scarcely sculptured: mantle-margin with striated chaffy scales, like *Magdalensis*, interspersed with transparent needles. 20–80 fm. *Cp.*

237. *Acanthochites avicula*, n. s. Like *arragonites*, but valves sculptured in large snake-skin pattern. 8–20 fm. r. *Cp.*

Family *Patellidæ*.

238. *Nacella instabilis*, Gld. E.E. Large: shape of *compressa*.
239. *Nacella incessa*/ Hds. Sulphur. Small: Ancyloid.
240. ?*Nacella subspiralis*, n. s. Shaped like *Emarginula rosea*, and may be a *Scutellina*. 10–20 fm. *Cp.*
241. *Nacella depicta*, Hds. Sulphur. Small, long, flat, smooth: colour in rays.
242. *Nacella paleacea*, Gld. Otia. Narrower, brown, striated at each end.
242 *b.* *Nacella* ?var. *triangularis*. Shorter: apex raised: scarcely striated: whitish, with brown spots.

Family *Acmæidæ*. (For synonyms, *v.* Reports *in locis.*)

243. *Acmæa patina*, Esch. Large, blackish or tessellated: with very fine distant striæ. Between tides, *Lord.*
244. *Acmæa pelta*, Esch. More conical; border narrow; smooth, with blunt ribs often obsolete. Between tides, *Lord.*
244 *b.* *Acmæa* ?var. *Asmi*, Midd. Stout, small, black, conical. Probably an abnormal growth of *pelta*, jun. (1 sp. beginning on *pelta*) *Cp.*
245. *Acmæa persona*, Esch. Smaller: apex posterior: colour blotched or freckled: sculpture in irregular ribs. Maz. Cat. no. 266. Var. *umbonata*, arched, with narrow distant ribs. Var. *digitalis*, apex near margin. Var. *textilis*, apex far from margin, approaching *pelta*.
246. *Acmæa scabra*, Nutt. Rve. Outside with close rows of fine granules: orange-red tint, glossy. Var. *limatula*, sculpture stronger, border black: perhaps= Maz. Cat. no. 265.
247. *Acmæa spectrum*, Nutt. Rve. Flattened, with very strong ribs, irregular.
248. *Acmæa* (?*pileolus*, Midd. var.) *rosacea*. Pink, small: like Herm specimens of *virginea*.
249. *Lottia gigantea*, Gray. Genus reconstituted: mantle with papillæ interrupted in front. Shell large, flat, dark, lustrous (=*Tecturella grandis*, Smiths. Inst. Check List).
250. *Scurria mitra*, Esch. Papillæ all round the mantle. White, conical: young sometimes faintly sculptured. In dead clam, 12 fm. *Lord.*
250 *b.* *Scurria* ?var. *funiculata*. With rounded riblets, somewhat nodulous.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
251. Lepeta cæcoides	—	—	—	—	P	—	—	—
252. Gadinia (Rowellia)	—	—	—	I	—	—	—	I
253. Fissurella volcano	M	B	C	I	—	—	?V	DI
254. Glyphis aspera..........	—	—	OC	P	—	V	V	—
255. —— densiclathrata	?B	B	C	—	—	—	—	M
256. Lucapina crenulata......	D	—	C	C	—	—	—	D
257. Puncturella cucullata	—	—	P	—	P	—	V	M
258. —— galeata............	—	—	P	—	P	—	V	—
259. —— Cooperi	—	—	—	—	—	—	—	I
260. Haliotis Cracherodii	D	C	C	FDIL	—	—	—	MI
261. —— splendens..........	D	C	C	DIL	—	—	—	MDI
262. —— corrugata..........	—	—	C	D	—	—	—	I
263. —— rufescens	—	C	C	D	—	—	—	M
264. —— Kamtschatkana	—	—	C	FI	—	—	V	DI
265. Phasianella compta......	—	BD	C	D	—	—	—	MDI
266. Pomaulax undosus	M	C	C	L	—	—	—	DI
267. Pachypoma gibberosum ..	—	—	—	M	—	—	V	MB

251. *Lepeta cæcoides*, ?n. s. Like *cæca*, but apex turned back. Farallone Is., teste R. D. Darbishire.

Family *Gadiniadæ*.

252. *Rowellia*, sp. Genus proposed by Cooper: tentacles flattened, pectinated. Cat. Is. *Cp.* Far. Is. *Row.*

Family *Fissurellidæ*.

253. *Fissurella volcano*, Rve. = *ornata*, Nutt. Approaches *Peruviana*: hole variable.
254. *Glyphis aspera*, Esch. = *Lincolni*, Gray = *cratitia*, Gld. Large, coarsely sculptured, with colour-rays.
255. *Glyphis densiclathrata*, Rve. Smaller: with closer, finer sculpture.
256. *Lucapina crenulata*, Sby. Tank. Very large: internal.
257. *Puncturella cucullata*, Gld. E.E. Large, with strong, variable ribs, 15–40. Hole simple.
258. *Puncturella galeata*, Gld. E.E. Scarcely differs from *noachina*, but tripartite process more strongly marked.
259. *Puncturella Cooperi*, n. s. Outside like *galeata*, but without props to the lamina. 30–120 fm. not r. *Cp.*

Family *Haliotidæ*.

260. *Haliotis Cracherodii*, Leach, auct. The trade species, smooth, dark olive: holes 5–9. Var. *Californiensis*, holes 9, 10, 11.
261. *Haliotis splendens*, Rve. Flatter, grooved, lustrous. Holes 4–7. Below tide: on rocks, *Cp.*
262. *Haliotis corrugata*, Gray. Large, arched, very rough. Holes 3–5. Below tide: on rocks, *Cp.*
263. *Haliotis rufescens*, Swains. Large, flatter, waved, rich orange-red. Holes 3–5. Below tide: on rocks, *Cp.*
264. *Haliotis Kamtschatkana*, Jonas. Small, thin, arched, waved. Holes 4, 5. Below tide: on rocks, Far. Is. *Cp.*

Family *Trochidæ*.

265. *Phasianella compta*, Gld. Otia. Maz. Cat. no. 284. Like *pullus*, a little longer and flatter; but operc. bevelled and striated. ? Var. *pulloides*, exactly like Herm shells: ? var. *elatior*, dwarfed, longer and flatter: var. *punctulata*, with close rows of dots; pillar chinked. 8–20 fm. *Cp.*
266. *Pomaulax undosus*, Wood. Very large: operculum with 2 ridges.
267. *Pachypoma gibberosum*, Chem. ? = *inæquale*, Mart. Large, rough: operc. swollen, simple. (Dead.)

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
268. ? Imperator serratus	—	—	—	—	—	—	—	MI
269. Leptonyx sanguineus	—	M	—	OFMI	—	—	V	MI
270. —— bacula	—	—	—	—	—	—	—	I
271. Liotia fenestrata	—	—	—	—	—	—	—	I
272. —— acuticostata	—	—	—	—	—	—	—	MI
273. Ethalia supravallata	—	—	—	—	—	—	—	D
273 *b*. —— *var.* invallata	—	—	—	—	—	—	—	D
274. Livona picoides	—	B	—	—	—	—	—	—
275. Trochiscus Norrisii	M	B	C	—	—	—	—	DI
276. —— convexus	—	M	—	—	—	—	—	—
277. Chlorostoma funebrale ..	M	C	C	FI	—	—	V	MD
277 *b*.—— *var.* subapertum	—	—	—	—	—	—	V	—
278. —— gallina	—	—	D	L	—	—	—	DI
279. —— brunneum	—	—	C	FMDI	—	—	—	M
280. —— Pfeifferi	—	M	C	—	—	—	—	D
281. —— aureotinctum	C	—	C	L	—	—	—	I
282. Omphalius fuscescens	B	M	C	D	—	—	—	DI
283. Calliostoma canaliculatum	M	C	C	M	—	—	V	M
284. —— costatum	M	C	C	VFMI	P	V	V	—
285. —— annulatum	M	—	C	M	—	V	V	—
286. —— variegatum	—	—	—	—	P	—	—	—

268. ? *Imperator serratus*, n. s. Small, finely sculptured, base stellate, nucleus Planorboid: operc. flat, with more whirls. 10–20 fm.=266 or 267 jun. teste *Cp.*
269. *Leptonyx sanguineus*, Linn. n. g. Like *Collonia*, not umbilicate. Operc. with horny and shelly layers, many whirls, outside flattish, not ribbed, margin broad. Species red or purple, lirate. Bch.–20 fm. *Cp.*
270. *Leptonyx bacula*, n. s. Small, ashy, Helicina-shaped, nearly smooth. Bch. d. *Cp.* Genus=*Homalopoma*, p. 537: nom. preoc.
271. *Liotia fenestrata*, n. s. Small. Strongly ribbed each way. Bch.–40 fm. d. *Cp.*
272. *Liotia acuticostata*, n. s. Small. Sharply keeled, without radiating sculpture. 10–20 fm. *Cp.*
273. *Ethalia supravallata*, n. s. Minute: with keel and furrow near suture.
273 *b*. *Ethalia* ? var. *invallata*. Without keel.
274. *Livona picoides*, Gld. Otia. Probably the remnant of an ancient colony of *pica*.
275. *Trochiscus Norrisii*, Sby. Tank. Nucleus as in *Solarium*: perhaps a Proboscidifer, though pearly.
276. *Trochiscus convexus*, n. s. Small, subturrited, whirls swollen: umbilicus with 2 ribs, the outer crenated.
277. *Chlorostoma funebrale*, A. Ad. P. Z. S. 1854, p. 316=*marginatum*, Nutt. non Rve. Blackish, often puckered near suture.
277 *b*. *Chlorostoma funebrale*, var. *subapertum*, with umbilical pit.
278. *Chlorostoma gallina*, Fbs. P. Z. S. 1850, p. 271. Olive, dashed with purple. Var. *pyriformis*, Gld., umbilicus partly or wholly open.
279. *Chlorostoma brunneum*, Phil. Auburn: finely striate: Gibbuloid aspect. The young (teste *Cp.*) has a basal rib.
280. *Chlorostoma Pfeifferi*, Phil. Like *brunneum*: outside Ziziphinoid: umbilicus keeled.
281. *Chlorostoma aureotinctum*, Fbs. P. Z. S. 1850, p. 271=*nigerrimum*, Gmel. ? Mus. Cum. Gibbuloid: with distant grooves and fine sculpture; mouth orange-spotted.
282. *Omphalius fuscescens*, Phil. Almost identical with *ligulatus*, Maz. Cat. no. 293.
283. *Calliostoma canaliculatum*, Mart.=*doliarium*. Large, with strong grooves.
284. *Calliostoma costatum*, Mart.=*filosum*, &c. Smaller, swollen, reddish; finely ribbed. 8–15 fm. *Lyall.*
285. *Calliostoma annulatum*, Mart.=*virgineum*. Large, granular, stained with violet.
286. *Calliostoma variegatum*, n. s. Small, more conical, nodules more distant, white on rosy ground.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
287. Calliostoma supragranosum	—	—	—	—	—	—	—	D
288. —— gemmulatum	—	—	—	—	—	—	—	D
289. —— splendens	—	—	—	—	—	—	—	MI
290. Phorcus pulligo	—	—	M	—	—	V	V	M
291. Gibbula parcipicta	—	—	—	FI	—	—	V	I
292. —— optabilis	—	—	—	—	—	—	—	D
293. —— funiculata	—	—	—	—	—	—	V	—
294. —— succincta	—	—	—	FIH	—	—	V	I
295. —— lacunata	—	—	—	—	—	—	V	—
296. Solariella peramabilis....	—	—	—	—	—	—	—	I
297. Margarita cidaris	—	—	—	—	—	—	V	—
298. —— pupilla............	—	—	P	VOI	P	V	V	—
298 *b*. —— *var.* salmonea	—	—	—	—	—	—	—	MI
299. —— acuticostata	—	B *fs.*	—	—	—	—	—	MI
300. —— inflata	—	—	—	—	P	V	V	—
301. —— lirulata	—	—	—	—	P	—	V	—
302. —— ? Vahlii	—	—	—	—	P	—	—	—
303. —— tenuisculpta	—	—	—	—	P	—	V	—
304. —— helicina	—	—	—	—	—	—	V	—

287. *Calliostoma supragranosum*, n. s. Swollen, with sharp ribs; posterior 1–4 granular.

288. *Calliostoma gemmulatum*, n. s. Very swollen: painted like *eximium*: with 2 principal and 2 smaller rows of granules.

289. *Calliostoma splendens*, n. s. Orange-chestnut, with fleshy nacre; small, rather flattened, base glossy. 6–40 fm. *Cp.*

290. *Phorcus pulligo*, Mart. + *maculosus*, A. Ad. = *euryomphalus*, Jonas + *marcidus*, Gld. Subgenus of *Gibbula*, with expanded, rounded umbilicus, and flat whirls; sometimes obsoletely ribbed.

291. *Gibbula parcipicta*, n. s. Like strong growth of *Marg. lirulata*, var.

292. *Gibbula optabilis*, n. s. Wider: decussated between ribs: 2 spiral lines inside umbilicus.

293. *Gibbula funiculata*, n. s. Shaped like *Montagui*: with rounded spiral riblets.

294. *Gibbula succincta*, n. s. Small, scarcely sculptured, with spiral brown pencillings.

295. *Gibbula lacunata*, n. s. Very small, nearly smooth; umbilicus hemmed-in by swelling of columella.

296. *Solariella peramabilis*, n. s. Subgenus of *Margarita*, with open, crenated umbilicus. Species most ornate, with delicate sculpture. Umbilicus with 3 internal spiral lines, crossed by lirulæ: operculum sculptured. Like *Minolia aspecta*, A. Ad. 40–120 fm. living, *Cp.*

297. *Margarita cidaris*, A. Ad. n. s. Large, knobby, like thin *Turcica*, with simple pillar and small umbilicus.

298. *Margarita pupilla*, Gld. E.E. = *calostoma*, A. Ad. Strong, with sharp ribs, decussated between, and fleshy nacre. 8–15 fm. *Lyall.*

298 *b*. *Margarita* ? var. *salmonea*. Between *pupilla* and *undulata*: salmon-tinted, sculpture fine, not decussated: sutures not waved. 6–40 fm. *Cp.*

299. *Margarita acuticostata*, n. s. Small, painting clouded: 3 sharp ribs on spire. 8–20 fm. *Cp.*

300. *Margarita inflata*, n. s. Thin, whirls very swollen; sculpture very fine; spiral hollow inside keeled umbilicus.

301. *Margarita lirulata*, n. s. Small: operc. smooth: 2 sharp principal riblets on spire: outline variable. Var. *subelevata*, raised, livid: var. *obsoleta*, sculpture evanescent: ? var. *conica*, very tall, with intercalary ribs, like *G. parcipicta.*

302. *Margarita Vahlii*, Möll. Raised, smooth: operc. with spiral rib.

303. *Margarita tenuisculpta*, ? n. s. Like *obsoleta*, but operc. ribbed.

304. *Margarita helicina*, Mont. Like the Finmark shells. Circumboreal.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
305. Crucibulum spinosum....	M	B	C	DIL	—	—	—	DI
306. Crepidula aculeata	B	—	—	—	—	—	—	—
307. —— dorsata	C	B	P	—	P	V	V	MD
308. —— excavata, *var.*	—	—	—	—	—	—	—	I
309. —— adunca............	—	B	OC	P	P	V	V	MDI
310. —— rugosa	B	B	C	C	—	—	—	DI
311. —— navicelloides	M	—	C	OI	—	V	V	I
311 *b.* —— *var.* nummaria	—	—	P	—	—	—	V	—
311 *c.* —— *var.* explanata	C	—	M	—	—	V	V	—
312. Galerus fastigiatus	—	—	P	—	P	V	V	—
313. —— contortus..........	—	—	—	—	—	—	—	MDI
314. Hipponyx cranioides	—	—	—	—	—	—	V	—
315. —— antiquatus	—	?B	—	—	—	—	—	?MI
316. —— serratus	—	—	—	—	—	—	—	I
317. —— tumens	—	B	—	—	—	—	—	MDI
318. Serpulorbis squamigerus. .	B	B	C	D	—	—	—	D
319. Bivonia compacta . . [gma	—	—	—	—	—	—	V	—
320. Petaloconchus macrophra-	D	—	—	—	—	—	—	—
321. Spiroglyphus lituella	B	—	—	C	—	—	—	—

Order PECTINIBRANCHIATA. Suborder ROSTRIFERA.

Family *Calyptræidæ.*

305. *Crucibulum spinosum*, Sby. Maz. Cat. no. 344. From Southern fauna.
306. *Crepidula aculeata*, Gmel. Maz. Cat. no. 334. From Southern fauna. Round the world.
307. *Crepidula ? dorsata*, Brod., var. *lingulata*, Gld. E.E.=var. *bilobata*, Maz. Cat. no. 336=*C. bilobata*, Rve. Appears identical with the S. American shells.
308. *Crepidula excavata*, Brod. Maz. Cat. no. 337. S. American.
309. *Crepidula adunca*, Sby. Tank.=*solida*, Hds.=*rostriformis*, Gld. E.E. Dark liver, rough epidermis, solid deck with produced sides. [Not *uncata*, Mke.=*rostrata*, C. B. Ad., Rve.=*adunca*, Maz. Cat. no. 338.] Between tides, *Lord*; 10 fm. *Cp.*
310. *Crepidula rugosa*, Nutt. P. Z. S. 1856, p. 224. Probably northern var. of *onyx*, Sby. Maz. Cat. 340, with epidermis less shaggy.
311. *Crepidula navicelloides*, Nutt. Shape of *squama*, with nucleus of *unguiformis* (Maz. Cat. no. 342). Rounded var. in hollow bivalves=*nummaria*, Gld. Var. drawn out in layers like *Lessonii*=*fimbriata*, Rve. Var. elongated in crypts, scooped by crab or bivalve=*explanata*, Gld.=*exuviata*, Nutt.=*perforans*, Val.
312. *Galerus fastigiatus*, Gld. E.E. Like *mamillaris*, nucleus large, immersed. Large, in 8–15 fm. *Lyall.*
313. *Galerus contortus*, n. s. Whirls twisted: nucleus minute, prominent. 20–40 fm. *Cp.*

Family *Capulidæ.*

314. *Hipponyx cranioides*, n. s. Large, rough, flat, intermediate between *planatus* and
315. *Hipponyx antiquatus*, Linn. Maz. Cat. no. 347. From Southern fauna.
316. *Hipponyx serratus*, Cpr. Maz. Cat. no. 346. From Southern fauna.
317. *Hipponyx tumens*, n. s. Growth like *Helcion*: sculpture more open than *barbatus*.

Family *Vermetidæ.*

318. *Serpulorbis squamigerus*, Cpr. P. Z. S. 1856, p. 226 (not *Aletes*). Large, scaly. *Verm. anellum*, Mörch, P. Z. S. 1861, p. 359, is perhaps the young.
319. *Bivonia compacta*, n. s. Entirely open within: but colour and growth like
320. *Petaloconchus macrophragma*, Cpr. Maz. Cat. no. 359. From Southern fauna.
321. *Spiroglyphus lituella*, Mörch, P. Z. S. 1861, p. 154.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
322. Cæcum crebricinctum....	—	—	—	—	—	—	—	MDI
323. —— Cooperi	—	—	—	—	—	—	—	DI
324. Turritella Cooperi	—	—	—	—	—	—	—	DI
325. —— Jewettii	—	B *fs.*	—	D ?*fos.*	—	—	—	—
326. Mesalia lacteola	—	—	—	—	P	V	—	—
326 *b.* —— *var.* subplanata ..	—	—	—	—	P	—	V	—
327. —— tenuisculpta	—	—	—	—	—	—	—	D
328. Cerithidea sacrata	MB	C	C	CF	—	—	—	FD
329. Bittium filosum	—	—	P	P	P	V	V	—
329 *b.* —— ?*var.* esuriens	—	B	—	—	—	—	V	MD
330. —— attenuatum........	—	—	—	M	—	—	—	—
331. —— quadrifilatum	—	—	—	D	—	—	—	D
332. —— asperum	—	B *fs.*	—	—	—	—	—	DI
333. —— armillatum	—	B *fs.*	—	—	—	—	—	D
334. —— fastigiatum	—	B	—	—	—	—	—	—
335. Litorina planaxis........	C	C	C	FDI	—	—	—	MDI
336. —— Sitchana	—	—	O	PO	P	V	V	—

Family *Cæcidæ*.

322. *Cæcum crebricinctum*, n. s. Large, with aspect of *Elephantulum*, but very fine close annular sculpture; plug subungulate. 8–20 fm. *Cp.*

323. *Cæcum Cooperi*, n. s. Small, with 30–40 sharp narrow rings.

Family *Turritellidæ*.

324. *Turritella Cooperi*, n. s. Extremely slender, with many narrow whirls. c. *Cp.*

325. *Turritella Jewettii*, n. s. Like *sanguinea*, with very faint sculpture.

326. *Mesalia lacteola*, ? n. s. May be a local var. of the circumpolar *lactea*, with altered sculpture: distinct, *teste* Cuming.

326 *b.* *Mesalia* ?var. *subplanata*. Sculpture fainter: whirls flattened.

327. *Mesalia tenuisculpta*, n. s. Very small, slender, whirls rounded, lip waved. Shoal-water, *Cp.*

Family *Cerithiadæ*.

328. *Cerithidea sacrata*, Gld. E.E.=*Californica*, Nutt.+*pullata*, Gld. Variable in shape and sculpture: passes into *Mazatlanica*, Maz. Cat. no. 395.

329. **Bittium filosum*, Gld. E.E.=*Eschrichtii*, Midd. Strong, broad, grooved.

329*b.* *Bittium* ? var. *esuriens*. Like starved *filosum*, very narrow, adult scarcely sculptured.

330. *Bittium attenuatum*, n. s. Like *plicatum*, A. Ad., or drawn-out *esuriens*, with threads instead of grooves.

331. **Bittium quadrifilatum*, n. s. Broad: 4 threads, equal from beginning, coiling over strong radiating ribs.

332. **Bittium asperum*, n. s. Same aspect: upper whirls with 2 strong and 2 faint keels over less prominent ribs. Bch.–40 fm. *Cp.*

333. **Bittium armillatum*, n. s. Same aspect: 3 nearly equal rows of knobs.

334. *Bittium fastigiatum*, n. s. Small, slender: apex normal: sutures indented, anterior rib strong.

Family *Litorinidæ*.

335. *Litorina planaxis*, Nutt. Phil.=*patula*, Gld. E.E. Outside plain; columella scooped.

336. *Litorina Sitchana*, Phil.=*sulcata*, Gld.=*rudis*, Coop. Rounded, flat, with spiral ribs. Var. *modesta*, Phil. (pars) has sculpture faint: *subtenebrosa*, Midd., is perhaps a degraded var. Rocks between tides, *Lord*; 8–10 fm. *Lyall* [?].

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* These species have so peculiar a nucleus that they can scarcely rank near *Cerithium* or *Rissoa*: perhaps they are related to *Alaba*. The nucleus of *esuriens* and *attenuatum* has not been seen.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
337. Litorina scutulata	—	B	PF	POFMI	P	V	V	MDI
338. ? Assiminea subrotundata	—	—	—	—	—	—	V	—
339. ? Paludinella	—	—	—	—	—	—	V	—
340. Lacuna vincta	—	—	—	—	P	—	V	—
341. —— porrecta	—	—	—	—	—	—	V	—
342. —— solidula	—	—	P	IO	P	V	V	—
342 *b*. —— *var.* compacta	—	—	—	—	—	—	V	—
343. —— variegata..........	—	—	—	—	—	—	V	—
344. —— unifasciata	—	B	B	I	—	—	—	DI
345. Isapis fenestrata	—	—	—	—	—	—	V	DI
346. —— obtusa	—	—	—	—	—	—	—	MBDI
347. Rissoina interfossa	—	—	—	—	—	—	—	MI
348. Rissoa compacta	—	—	—	—	P	—	V	—
349. —— acutelirata	—	—	—	—	—	—	—	D
350. Alvania reticulata	—	—	—	—	—	—	V	—
351. —— filosa	—	—	—	—	—	—	V	—
352. Fenella pupoidea	—	—	—	—	—	—	—	M
353. Barleeia subtenuis	—	—	—	DI	—	—	—	DI
353 *b*. —— ?*var.* rimata	—	—	—	D	—	—	—	D
354. —— haliotiphila	—	—	—	II	—	—	—	—
355. Amphithalamus inclusus	—	B	—	—	—	—	—	D

337. *Litorina scutulata*, Gld. E.E.+*lepida*, Gld. Var.=*plena*, Gld. Small, solid, pointed, flattened, smoothish. Rocks between tides, *Lord.*
338. ? *Assiminea subrotundata*, n. s. Like a very thin *Litorina*: ashen, plain.
339. ? *Paludinella*, sp. May be an aberrant *Assiminea.*
340. *Lacuna vincta*, Mont. auct. Circumboreal.
341. *Lacuna porrecta*, n. s. Upper whirls flattened, effuse anteriorly; chink large.
341 *b*. *Lacuna* ?var. *effusa.* Larger, taller, more swollen.
341 *c*. *Lacuna* ?var. *exæquata*, same shape but flattened.
342. *Lacuna solidula*, Lov.=*carinata*, Gld., not A. Ad.=*Modelia striata*, Gabb. Solid, variable, chink small; sometimes keeled or angular.
342 *b*. *Lacuna* ?var. *compacta.* Very small, narrow, orange, scarcely chinked.
343. *Lacuna variegata*, n. s. Very tall, effuse, irregular with wide chink: clouded or with zigzag stripes: like *decorata*, A. Ad.
344. *Lacuna unifasciata*, Cpr. P. Z. S. 1856, p. 205. Small, glossy, generally with a coloured keel, sometimes broken into dots. Var. *aurantiaca*, keel obsolete, resembling the chinked *Phasianellæ.* 8–10 fm. *Cp.*
345. *Isapis fenestrata*, n. s. Like *ovoidea*, with sharp distant ribs.
346. *Isapis obtusa*, n. s. Whirls flattened behind: ribs swollen, uneven. 10–20 fm. *Cp.*

Family *Rissoidæ.*

347. *Rissoina interfossa*, n. s. With 5 sharp keels crossing 14 strong ribs. 8–10 fm.
348. *Rissoa compacta*, n. s. Sculptured like *Beanii*, with short broad whirls.
349. *Rissoa acutelirata*, n. s. Alvanoid: 15 sharp, distant, spiral riblets, travelling over 18 sharp distant ribs, obsolete in front.
350. *Alvania reticulata*, n. s. Open network: radiating threads travelling over 12 stronger distant spiral threads.
351. *Alvania filosa*, n. s. Turrited: pillar purple-stained: 18 close spiral striæ, passing over very faint waved riblets.
352. *Fenella pupoidea*, n. s. Variegated, truncatelloid shape. 20 fm. rare, *Cp.*
353. *Barleeia subtenuis*, n. s.=*Hydrobia* ?*ulvæ*, Maz. Cat. no. 417; but with normal Barleeoid operculum. On grass, *Cp.*
353 *b*. *Barleeia* ?var. *rimata.* Whirls more swollen: base chinked.
354. *Barleeia haliotiphila*, n. s. Longer, narrower, much smaller. On *H. splendens.*
355. *Amphithalamus inclusus*, n. g., n. s. Habit of minute *Nematura*; labrum not contracted, but labium in adult travels forward to meet it, leaving a chamber behind. Nucleus cancellated: base bluntly ribbed.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
356. ?Amphithalamus lacunatus	—	—	—	—	—	—	—	D
357. Truncatella Californica ..	—	—	—	—	—	—	—	D
358. Jeffreysia Alderi	—	—	—	D	—	—	—	—
359. —— translucens	—	—	—	—	—	—	—	D
360. Cithna albida	—	—	—	—	—	—	—	D
361. Diala marmorea	—	—	—	H	—	—	—	MD
362. —— acuta	—	—	—	—	—	—	—	MI
363. Styliferina turrita	—	—	—	—	—	—	—	D
364. Radius variabilis........	—	? B	—	—	—	—	—	—
365. Luponia spadicea	—	C	C	—	—	—	—	DI
366. Trivia Californica	—	B	C	L	—	—	—	DI
367. —— Solandri	—	—	—	L	—	—	—	I
368. Erato vitellina..........	—	B	C	—	—	—	—	DI
369. —— columbella	—	B	C	L	—	—	—	MDI
370. Myurella simplex	—	B	—	—	—	—	—	D
371. Drillia inermis..........	—	B	C	—	—	—	—	BDI
372. —— incisa	—	—	—	—	P	—	V	—
373. —— mœsta	—	B	—	—	—	—	—	D
374. —— torosa	—	—	—	M	—	—	—	M
374 *b*. —— *?var.* aurantia	—	—	—	D	—	—	—	D

356. *? Amphithalamus lacunatus,* n. s. Same nucleus; base chinked, not keeled. (Adult not found.)

Family *Truncatellidæ.*

357. *Truncatella Californica,* Pfr. Pneum. Viv. Suppl. vol. ii. p. 7.

Family *Jeffreysiadæ.*

358. *Jeffreysia Alderi,* Cpr. Maz. Cat. no. 420.
359. *Jeffreysia translucens,* n. s. Possibly a *Barleeia*: pillar thickened, base rounded.
360. *Cithna albida,* n. s. Very close to *C. tumens,* Maz. Cat. no. 421, but umbilicus angled, not keeled.

Family *Planaxidæ.*

361. *Diala marmorea,* n. s. Solid, glossy, clouded with red: base faintly angled.
362. *Diala acuta,* n. s. Base flattened, sharply angled: turrited. Bch.–10 fm. *Cp.*
363. *Styliferina turrita,* n. s. Minute, slender, base rounded.

Family *Ovulidæ.*

364. *Radius variabilis,* C. B. Ad. Maz. Cat. no. 435. Probably exotic.

Family *Cypræidæ.*

365. *Luponia spadicea,* Gray. Like *onyx,* but light-coloured.
366. *Trivia Californica,* Gray. Small: ribs sharp, distant.
367. *Trivia Solandri,* Gray. Maz. Cat. no. 441. From Southern fauna. Sta. Barb. and St. Nich. Is. common, *Cp.*
368. *Erato vitellina,* Hds. Sulph. Large, wide-mouthed: paries callous.
369. *Erato columbella,* Mke.=*leucophæa,* Gld. Maz. Cat. p. 537. Perhaps a var. of *Maugeræ,* from the tropics. 20–40 fm. c. *Cp.*

Suborder Toxifera. Family *Terebridæ.*

370. *Myurella simplex,* n. s. Sculpture very faint and variable: shape of *albocincta.* c. *Cp.*

Family *Pleurotomidæ.*

371. *Drillia inermis,* Hds. Sulph. Early whirls close sculptured. Beach–16 fm. living. *Cp.*
372. *Drillia incisa,* n. s. Like *inermis*: spiral sculpture grooved, not raised.
373. *Drillia mœsta,* n. s. Like large *luctuosa*: middle whirls with long transverse ribs and posterior knobs; adult obsolete.
374. *Drillia torosa,* n. s. Whirls rounder, olivaceous: with one row of strong bosses throughout: no posterior knobs.
374 *b*. *Drillia* ?var. *aurantia.* Orange, with sutural riblet and faint spiral sculpture.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
375. Drillia penicillata	—	—	—	L	—	—	—	—
376. —— cancellata	—	—	—	—	P	—	—	—
377. Mangelia levidensis	—	—	—	—	P	—	V	—
378. —— tabulata	—	—	—	—	—	—	V	—
379. —— interfossa	—	—	—	—	—	—	V	—
380. —— crebricostata	—	—	—	—	—	—	V	—
381. —— variegata	—	B	—	—	—	—	—	—
381 *b*. —— ?*var.* nitens	—	B	—	—	—	—	—	—
382. —— angulata	—	B	—	—	P	—	—	M
383. Bela fidicula	—	—	P	—	P	V	—	—
384. —— excurvata	—	—	—	—	P	—	—	—
385. ? Daphnella aspera	—	—	—	M	—	—	—	—
386. ? —— filosa	—	B	—	—	—	—	—	—
387. ? —— effusa	—	—	—	—	—	—	V	—
388. Conus Californicus	—	B	C	D	—	—	—	DI
389. Obeliscus ?variegatus	—	—	—	L	—	—	—	D
390. Odostomia nuciformis	—	—	—	—	—	—	V	—
390 *b*. —— ?*var.* avellana	—	—	—	—	—	—	V	—
391. —— satura	—	—	—	—	—	—	V	—
391 *b*. —— ?*var.* Gouldii	—	—	—	—	—	—	V	—
392. —— gravida	—	B	—	—	—	—	—	D
393. —— inflata	—	—	—	—	—	—	V	—

375. *Drillia penicillata*, n. s. Like *inermis*, with delicate brownish pencillings.
376. *Drillia* cancellata*, ? n. s. Like the young of *incisa*, but nodosely cancellated.
377. *Mangelia levidensis*, n. s. Stumpy, purplish brown, with rough sculpture.
378. *Mangelia tabulata*, n. s. Stout, strongly shouldered, coarsely cancellated. Pillar abnormally twisted.
379. *Mangelia interfossa*, n. s. Like *attenuata*, delicately cancellated.
380. *Mangelia crebricostata*, n. s. Like *septangularis*, with closely set ribs.
381. *Mangelia variegata*, n. s. Small, slender, thin, zoned with brown: 9 narrow ribs, and strong spiral striæ.
381 *b*. *Mangelia* ?var. *nitens*. Glossy: spiral lines almost obsolete.
382. *Mangelia angulata*, n. s. Shape of *variegata*, but brown, whirls broad, angular.
383. *Bela fidicula*, Gld. E.E. Very close to *turricula*, var. 8–10 fm. *Lyall.*
384. *Bela excurvata*, n. s. Like *Trevelliana*: stumpy, Chrysalloid.
385. ?*Daphnella*† *aspera*, n. s. Elongated, with coarse fenestration.
386. ?*Daphnella*† *filosa*, n. s. Small, diamond-shaped, but rounded periphery; spirally threaded.
387. ?*Daphnella*† *effusa*, nom. prov. Thin, extremely drawn-out, sculpture faint.

Family *Conidæ*.

388. *Conus Californicus*, Hds. Sulph.=*ravus*, Gld. Chestnut, plain.

Suborder PROBOSCIDIFERA. Family *Pyramidellidæ*.

389. *Obeliscus ?variegatus*, n. s. From Gulf fauna. Periphery with spiral groove. Colour-pattern clouded.
390. *Odostomia nuciformis*, n. s. Very large, solid, Tornatelloid.
390 *b*. *Odostomia* ?var. *avellana*. Shape of *conoidalis*.
391. *Odostomia satura*, n. s. Large, with swollen whirls like *Bithinia similis*.
391 *b*. *Odostomia* ?var. *Gouldii*. Taller, base gently rounded.
392. *Odostomia gravida*, Gld. Otia. Like *conoidalis*, but nucleus minute.
393. *Odostomia inflata*, n. s. Like large *dolioliformis*: with most minute spiral striulation. Farallone Is. On *Hal. rufescens*, teste Darbishire.

* A peculiar group of species, resembling *Clionella* (marine, teste *Stimpson*.)

† Generic position of all these doubtful: perhaps they belong to genera not yet eliminated: *filosa* resembling the Eocene forms between *Conus* and *Pleurotoma*.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
394. Odostomia straminea	—	—	—	H	—	—	—	C
395. —— tenuisculpta	—	—	—	—	—	—	V	—
396. Chrysallida cincta	—	—	—	—	—	—	—	I
397. —— pumila............	—	—	—	—	—	—	—	DI
398. Dunkeria laminata	—	B	—	—	—	—	—	D
399. Chemnitzia tridentata ..	—	B	—	—	P	—	—	MD
400. —— chocolata.........	—	—	—	—	—	—	—	D
400*b*.—— *var.* aurantia	—	B	—	—	P	—	—	—
401. —— tenuicula..........	—	B	B	—	—	—	—	D
401*b*.—— ?*var.* subcuspidata..	—	—	—	—	—	—	—	D
402. —— crebrifilata	—	B	—	—	—	—	—	—
403. —— torquata	—	B	—	—	P	V	—	—
403*b*.—— ?*var.* stylina	—	B	—	—	—	—	—	M
404. —— virgo	—	B	—	—	—	—	—	—
405. Eulima micans	—	—	—	—	P	—	V	DI
406. —— compacta..........	—	—	—	—	—	—	—	D
407. —— rutila	—	—	—	—	—	—	—	M
408. —— thersites	—	B	—	—	—	—	—	—

394. *Odostomia straminea*, n. s. Like tall var. of *inflata*, with straw-coloured epidermis, not striulate.

395. *Odostomia tenuisculpta*, n. s. Like *sublirulata*, Maz. Cat. no. 487, with obsolete sculpture throughout.

396. *Chrysallida cincta*, n. s. Passing towards *Mumiola*. Radiating sculpture very faint.

397. *Chrysallida pumila*, n. s. Like *ovulum*, Maz. Cat. no. 512, but slender; spiral lines delicate.

398. *Dunkeria laminata*, n. s. Subgenus of *Chemnitzia*, with rounded whirls: typical species. Aspect of *Fenella*, finely cancellated.

399. *Chemnitzia tridentata*, n. s. Large, chestnut: 19–24 ribs, evanescent at periphery: waved interspaces with 8–10 spiral grooves: labrum with 3 teeth, hidden as in *Obeliscus*: base round.

400. *Chemnitzia chocolata*, n. s. Same size and colour: not toothed: base prolonged: crowded ribs minutely striulate between.

400*b*. *Chemnitzia* ?var. *aurantia*. Intermediate between the above: orange, base round; 26 ribs, striulate between.

401. *Chemnitzia tenuicula*, Gld. Otia. Shape of *tridentata* dwarfed: whirls flatter, base prolonged, spiral grooving strong.

401*b*. *Chemnitzia* ?var. *subcuspidata*. Ribs more distant, muricated at sutures.

402. *Chemnitzia crebrifilata*, n. s. Slender, whitish: with 8 spiral threads passing over 24 ribs, evanescent round base.

403. *Chemnitzia torquata*, Gld. Otia = *Vancouverensis*, Gld. Ribs truncated before periphery, leaving plain band above sutures.

403*b*. *Chemnitzia* ?var. *stylina*. Like *torquata*, tapering, less swollen in front, with more ribs, band less marked.

404. *Chemnitzia virgo*, n. s. Very slender, with short, smooth base: 18 ribs, evanescent at periphery, and 8 spiral grooves.

Family *Eulimidæ*.

405. *Eulima micans*, ? n. s. Perhaps a small var. of the European *polita*. 30–40 fm. living. *Cp.*

406. *Eulima compacta*, ? n. s. Small, with blunt spire and elongated base.

407. *Eulima rutila*, ? n. s. Leiostracoid, rosy, base lengthened. Like *producta*, Maz. Cat. no. 551.

408. *Eulima thersites*, n. s. Very broad, short, twisted.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
409. Scalaria Indianorum	—	—	—	—	—	—	V	—
409*b*.—— ?*var.* tincta	—	—	—	L	—	—	—	D
410. —— ?Cumingii	—	—	—	—	—	—	—	D
410*b*.—— ?gracilis	—	—	—	D	—	—	—	—
411. —— subcoronata	—	—	—	—	—	—	—	M
412. —— crebricostata	—	—	—	—	—	—	—	MD
413. —— bellastriata	—	—	—	—	—	—	—	M
414. Opalia borealis	—	—	P	—	—	—	V	—
415. —— ?*var.* insculpta	—	B*fs.*	—	—	—	—	—	—
416. —— spongiosa	—	—	—	—	—	—	—	M
417. —— retiporosa	—	—	—	—	—	—	—	I
418. —— bullata............	—	B	—	—	—	—	—	—
419. Cerithiopsis tuberculata..	—	B	—	—	—	—	V	MD
420. —— columna	—	—	—	—	—	—	V	M
421. —— munita	—	—	—	—	—	—	V	—
422. —— purpurea	—	B	—	—	—	—	—	MD
423. —— fortior	—	B	—	—	—	—	—	—
424. —— assimilata	—	—	—	—	—	—	—	I
425. Triforis ?adversa	—	—	—	—	—	—	V	I
426. Cancellaria modesta	—	—	—	—	—	—	V	—

Family *Scalariadæ.*

409. *Scalaria Indianorum,* ? n. s. Between *Turtonis* and *communis*: like " *Georgettina,* Kien. Mus. Cum. no. 34, Brazil."

409*b*. *Scalaria* ?var. *tincta.* Purple-brown behind: like *regularis,* without spiral sculpture.

410. *Scalaria ? Cumingii,* Cpr. P. Z. S. 1856, p. 165.

410*b*. *Scalaria ?gracilis,* Sby. in Mus. Cum.

411. *Scalaria subcoronata,* n. s. Like young *communis,* with more and sharper ribs, faintly coronated when adolescent.

412. *Scalaria crebricostata,* n. s. = Mus. Cum. no. 32: 15 sharp reflexed ribs, coronated against the sutures.

413. *Scalaria bellastriata,* n. s. Shape like *pretiosa,* jun.: ribs very close, spinous at shoulder, crossed by spiral riblets.

414. *Opalia borealis,* Gld. E. E. Very close to *australis*: obsolete forms like *Ochotensis,* Midd.

415. *Opalia* (?*crenatoides,* var.) *insculpta.* Like the C. S. L. form and *crenata,* but ribs closer, without spiral sculpture, sutural holes behind the basal rib.

416. *Opalia spongiosa,* n. s. Like small, very slender *granulata*: surface riddled with deep punctures in spiral rows.

417. *Opalia retiporosa,* n. s. Sculpture in network, with deep holes. 40 fm. d. r. *Cp.*

418. *Opalia bullata,* n. s. Shape of *Rissoina*: with sutural bosses: no basal rib.

Family *Cerithiopsidæ.*

419. *Cerithiopsis tuberculata,* Mont. Fbs. & Hanl. Agrees with the British rather than with the Mazatlan form, Cat. no. 557.

420. *Cerithiopsis columna,* n. s. Very tall: nodules close, like strung figs.

421. *Cerithiopsis munita,* n. s. Stout: strongly sculptured: base evenly ribbed.

422. *Cerithiopsis purpurea,* n. s. Stained with purple: nodules fine: base finely lirate.

423. *Cerithiopsis fortior,* n. s. Sculpture open: strong basal rib.

424. *Cerithiopsis assimilata,* C. B. Ad. Maz. Cat. no. 563. With spiral keels. From Southern fauna.

425. *Triforis ?adversa,* Mont. Fbs. & Hanl. Agrees with British specimens. 10–40 fm. v. r. *Cp.*

Family *Cancellariadæ.*

426. *Cancellaria modesta,* n. s. Like *Trichotropis borealis,* with two slanting plaits and spiral ribs travelling up the paries. See also p. 615, nos. 463, 817.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
427. Trichotropis cancellata ..	—	—	P	—	P	—	V	—
428. —— inermis	—	—	—	—	—	—	V	—
429. Velutina lævigata	—	—	—	—	P	—	V	—
430. —— prolongata	—	—	—	—	—	—	V	—
431. Natica clausa	—	—	P	—	P	—	V	—
432. Lunatia Lewisii	—	C	P	P	P	—	V	D
433. —— pallida............	—	—	P	—	P	V	V	—
434. Neverita Recluziana	—	—	—	D	—	—	—	D
435. Priene Oregonensis......	—	—	P	VP	P	V	V	M
436. Ranella Californica......	—	—	—	L	—	—	—	BD
437. Mitra maura	C	—	—	I	—	—	—	DI
438. Marginella Jewettii	—	B	—	—	—	—	—	MI
439. —— subtrigona	—	B	—	—	—	—	—	—
440. —— regularis	—	B	—	—	—	—	—	MDI
441. Volutella pyriformis	—	—	—	F	—	—	—	D
442. Volvarina varia	—	B	—	—	—	—	—	DI
443. Olivella biplicata........	C	C	C	D	—	—	V	MDI
444. —— bætica............	—	B	OC	M	P	—	V	D

427. *Trichotropis cancellata*, Hds. Sulph. Sculpture strong, open. Epidermis bristly.
428. *Trichotropis inermis*, Hds. Sulph. Sculpture faint: not bristly.

Family *Velutinidæ*.

429. *Velutina lævigata*, Linn. Fbs. & Hanl. Exactly accords with British specimens. ? = *Kamtschatkana*, Desh.
430. *Velutina prolongata*, n. s. Spire very small. Labrum produced in front.

Family *Naticidæ*.

431. *Natica clausa*, Brod. & Sby. Umbilicus closed. Operc. shelly. Circumboreal.
432. *Lunatia Lewisii*, Gld. E. E. = *herculæa*, Midd. Whirls flattened behind. Abundant on beach, *Cp.*
433. *Lunatia pallida*, Br. & Sby. = *caurina* + *soluta*, Gld. Globular, compact, whitish. Boreal.
434. *Neverita Recluziana*, Petit, Rve. Large, solid, raised, with brown grooved lump on pillar. Also Guaymas.

Family *Tritonidæ*.

435. *Priene Oregonensis*, Redf. Like *cancellata*, but coarser sculpture. 6 fm. *Lyall.*
436. *Ranella Californica*, Hds. Sulph. Scarcely differs from fine specimens of *R. ventricosa*, in Mus. Cum.

Family *Fasciolaridæ*.

437. *Mitra maura*, Swains. Nutt. = *orientalis*, Gray = '*Chilensis*, Gray,' Kien. Very dark and plain. Peru. Sand between rocks, l. w. *Cum.* Peru.

Family *Marginellidæ*.

438. *Marginella Jewettii*, Cpr. P. Z. S. 1856, p. 207. Like the Mogador species, somewhat shorter and broader. 10–20 fm. *Cp.*
439. *Marginella subtrigona*, n. s. Shape of *Erato columbella*.
440. *Marginella regularis*, n. s. Between *Jewettii* and *minor*, C. B. Ad. Maz. Cat. no. 587. Beach–20 fm. *Cp.*
441. *Volutella pyriformis*, n. s. Genus of Swainson (not D'Orb.) = *Closia*, Gray. Like *V. margaritula*, Maz. Cat. no. 589, but produced in front.
442. *Volvarina varia*, Sby. C. S. Lucas, W. Indies.

Family *Olividæ*.

443. *Olivella biplicata*, Sby. Tank. = *glandinaria*, Nutt. Nut-shaped.
444. *Olivella bætica*, n. s. Narrow, dull, thin: has been erroneously called *anazora, tergina, petiolita,* and *rufifasciata.*

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
445. Nassa fossata	—	—	PC	—	P	—	V	D
446. —— perpinguis	—	B	C	(?P)L	—	—	—	BDI
447. —— insculpta	—	—	—	—	—	—	—	I
448. —— mendica	—	C	P	POF	P	V	V	MD
449. —— Cooperi	—	—	?	—	—	—	—	DI
450. —— tegula	—	—	LC	L	—	—	—	D
451. Amycla gausapata	—	B	P	VD	P	V	V	M
452. —— ? Californiana	—	B	C	—	—	—	—	—
453. —— tuberosa	—	B *fs.*	—	—	—	—	V	MDI
454. ? —— chrysalloidea	—	—	—	—	—	—	—	D
455. ? —— undata	—	—	—	—	—	—	—	I
456. ? Truncaria corrugata	—	—	O	VPFMI	P	—	V	DI
457. Columbella carinata	—	B	C	—	—	—	—	MDI
457*b*. —— ?*var.* Hindsii	—	B	D	—	—	—	V	MD
458. Purpura crispata	C	F	C	VPOF	P	V	V	F
459. —— canaliculata	—	—	—	VF	—	V	V	—
460. —— saxicola	—	C	C	VPF	P	V	V	FI
460*b*. —— *var.* fuscata	—	—	?	—	—	—	V	—
460*c*. —— *var.* emarginata	B	B	C	D	—	—	—	D
460*d*. —— *var.* ostrina	—	F	C	POC	P	V	V	FD

Family *Buccinidæ.*

445. *Nassa fossata*, Gld. E. E. = *elegans*, Rve. non Desh. Large, broad, flattened spire.
446. *Nassa perpinguis*, Hds. Sulph. Same type, smaller, rounder, narrower.
447. *Nassa insculpta*, n. s. *Zeuxis*, with varix and non-reflexed callus. Spirally grooved. 40 fm. living, r. *Cp.*
448. *Nassa mendica*, Gld. E. E. + *Gibbesii*, Coop. = *Woodwardii*, Fbs. Very variable: some forms approach *trivittata.*
449. *Nassa Cooperi*, Fbs. P. Z. S. 1850, p. 273. Like *mendica*, with 7 distant ribs, and fine spiral sculpture.
450. *Nassa tegula*, Rve. Maz. Cat. no. 624. From Southern fauna.
451. *Amycla gausapata*, Gld. E. E. (Genus rearranged for Columbellids with Nassoid opercula, probably including *Alia* and *Astyris.*) Strong, solid, variegated, smooth.
452. *Amycla ? Californiana*, Gask. P. Z. S. 1851, p. 12. Whirls more swollen.
453. *Amycla tuberosa*, n. s. Very close to *minor*, Scacchi, but with different nucleus. 8–10 fm. c. *Cp.*
454. ? *Amycla chrysalloidea*, n. s. Shape of *Truncaria eurytoides*, but mouth not effuse: spirally furrowed. Shoal-water, *Cp.*
455. ? *Amycla undata*, n. s. Like stumpy, small *corrugata*, with waved sculpture. 40 fm. not r. *Cp.*
456. ? *Truncaria corrugata*, Rve. Conch. Ic. ("*Buccinum*:" "*Pisania*," Add. May be an *Amycla.*) Large, with waved ribs and spiral striæ. Dwarfed at 40 fm. *Cp.*
457. "*Columbella*" *carinata*, Hds. Sulph. Small, turrited, smooth, with stout posterior keel. (Perhaps *Amycla.*) Beach, *Cp.*
457*b*. *Columbella* ?var. *Hindsii*, Rve. Keel shorter, till it ceases, as in *gausapata.*

Family *Purpuridæ.*

458. *Purpura crispata*, Chem. = *plicata*, Mart. = *lactuca*, Esch. = *septentrionalis*, Rve. + &c. Large, strong, canal distinct, smooth or foliated.
459. *Purpura canaliculata*, Ducl. = *decemcostata*, Midd. + *attenuata*, Rve. + *analoga*, Fbs. With elegant spiral grooves. Chrysodomoid.
460. *Purpura saxicola*, Val. = *lapillus*, Coop. Like the Atlantic species, rough, pillar scooped, with brown spiral lines.
460*b*. *Purpura* var. *fuscata*, Fbs. Raised thin form, dull, with faint sculpture.
460*c*. *Purpura* var. *emarginata*, Desh. Short, swollen, with scaly sculpture.
460*d*. *Purpura* var. *ostrina*, Gld. E. E. Short, swollen, nearly smooth.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
461. Monoceros engonatum ..	B	—	C	D	—	—	—	DI
461 *b*. —— ?*var.* spiratum	—	—	—	—	—	—	—	I
462. —— lapilloides	B	—	C	D	—	—	—	I
463. Ocinebra lurida and vars.	—	B *fs.*	—	FI	—	V	V	M jun. I
464. —— interfossa..........	—	—	—	MI	P	V	V	M jun.
465. ? —— Poulsoni	C	? B	—	L	—	—	—	—
466. Cerostoma foliatum	—	—	O	PODI *fs.*	P	V	V	—
467. —— Nuttallii	B	B	C	—	—	—	—	DI
468. —— monoceros	—	—	C	L	—	—	—	? D
469. Chorus Belcheri	—	—	D	I	—	—	—	D
470. Nitidella Gouldii........	—	B	—	M	P	—	V	MD
471. Pedicularia Californica ..	—	—	—	(I)	—	—	—	—
472. Pteronotus festivus......	—	C	L	D	—	—	—	D
473. Muricidea Californica....	—	—	LC	—	—	—	—	MBDI
474. Trophon multicostatus ..	—	—	—	—	P	V	V	—
475. —— Orpheus	—	—	P	—	P	V	—	—
476. —— triangulatus	—	—	—	—	—	—	—	I
477. Siphonalia Kellettii	—	—	?	D	—	—	—	BD
478. —— fuscotincta	—	B	—	—	—	—	—	—
479. Chrysodomus tabulatus ..	—	B *fs.*	—	—	?Pjn	V	V	? I
480. —— liratus	—	—	A	V	—	—	—	—

461. *Monoceros engonatum*, Conr. = *unicarinatum*, Sby. Brown-dotted, with sharp posterior keel, smoothish. Beach, *Cp.*

461 *b*. *Monoceros* ?var. *spiratum* (Blainv.). Light colour; scaly: horn not developed.

462. *Monoceros lapilloides*, Conr. = *punctatum*, Gray + *brevidens*, Conr. Not shouldered: shape of *lapillus*.

463. *Ocinebra lurida*, Midd. (Genus reconstituted for Muricoid Purpurids with irregular varices.) Like *canaliculata*, brown, with swelling ribs. Beach on Cat. Is. living. *Cp.*

463 *b*. *Ocinebra* var. *aspera*, Baird. Sculpture rough.

463 *c*. *Ocinebra* var. *munda*. Tall, with faint sculpture.

464. *Ocinebra interfossa*, n. s. Purple-brown, with latticed sculpture.

465. ? *Ocinebra Poulsoni*, Nutt. Shape like *M. monoceros*, with brown spiral lines.

466. *Cerostoma foliatum*, Gmel. = *monodon*, Esch. Large, with winged varices.

467. *Cerostoma Nuttallii*, Conr. Smaller, pear-shaped: interstices scarcely sculptured.

468. *Cerostoma monoceros*, Sby. Spire raised: whirls rough, rounded.

469. *Chorus Belcheri*, Hds. Sulph. Very large, with irregular varices like *Trophon*. L. w. com. *Cp.*

470. *Nitidella Gouldii*, Cpr. P. Z. S. 1856, p. 208. Slender: like thin *A. gausapata*, with Purpuroid operc.

471. *Pedicularia Californica*, Newc. Small, purple, highly sculptured.

Family *Muricidæ*.

472. *Pteronotus festivus*, Hds. Sulph. Form irregular; frills reflexed.

473. *Muricidea Californica*, Hds. Sulph. Varices faintly developed. L.w.–20 fm. *Cp.*

474. *Trophon multicostatus*, Esch. = *Gunneri*, Lov. Rve. Frills spiny behind: not sculptured spirally. Circumpolar.

475. *Trophon Orpheus*, Gld. E. E. Like the last, with distant spiral riblets.

476. *Trophon triangulatus*, n. s. Typhoid shape: frills triangular, white. 60 fm. *Cp.*

477. *Siphonalia Kellettii*, Fbs. P. Z. S. 1850, p. 274. Very large, turrited, with swollen whirls. Also Japan. 1 living $6\frac{1}{2}$ in. long.

478. *Siphonalia fuscotincta*, n. s. Like the same in extreme miniature.

479. *Chrysodomus tabulatus*, Baird, P. Z. S. 1863, p. 66. Large, with posterior keel, and delicate sculpture. 120 fm. dead, Cat. Is. *Cp.*

480. *Chrysodomus liratus*, Mart. = *decemcostatus*, Midd. (? Say) = *Middendorffii*, Coop. Swollen, with distant keels. Whidby's Is.

	Nutt.	Jew.	B. A.	Smiths. Ins.	Ken.	Lord.	Swan.	Cooper.
481. Chrysodomus dirus	—	—	P	VI	P	V	V	—
482. —— rectirostris	—	—	—	—	P	—	—	—
483. Fusus ambustus	—	B *fs.*	C	FMI	—	—	—	BDI
484. Macron Kellettii	—	—	L	L	—	—	—	? I
485. —— lividus	—	—	—	L	—	—	—	D
486. Anachis subturrita	—	—	—	—	—	—	—	D
487. ? —— penicillata........	—	B	—	—	—	—	—	DI
488. Argonauta Argo	—	—	—	—	—	—	—	I
489. Octopus punctatus	—	—	—	(FL)	? P	—	? V	I
490. Ommastrephes giganteus .	—	—	—	—	—	—	—	I
491. —— Ayresii	—	—	—	—	—	—	—	I
492. Onychoteuthis fusiformis .	—	—	—	? M	? P	—	—	I

481. *Chrysodomus dirus,* Rve. = *incisus,* Gld. = *Sitchensis,* Midd. Dark liver, with spiral grooves.
482. *Chrysodomus rectirostris,* n. s. Small, white, smooth, with straight canal.
483. *Fusus ambustus,* Gld. Otia. Close to *clavata,* Brocchi, from Mediterranean. Farallone Is. teste Darbishire; 16 fm. c. *Cp.*
484. *Macron Kellettii,* A. Ad. P. Z. S. 1853, p. 185. Large, with blunt keels. Dead, 60 fm. Cat. Is. *Cp.*
485. *Macron lividus,* A. Ad. Small, smooth.
486. *Anachis subturrita,* n. s. Aspect of small *Rissoina.* 20 faint ribs: no spiral sculpture.
487. ?*Anachis penicillata,* n. s. Small, with Metuloid sculpture. Beach–10 fm. *Cp.*

Class CEPHALOPODA. Family *Argonautidæ.*

488. *Argonauta Argo,* Linn. auct. Like the Mediterranean form. Hundreds on Sta Cruz Is. *Cp.*

Family *Octopidæ.*

489. *Octopus punctatus,* Gabb, Proc. Cal. Ac. 1862, p. 170. S. Clemente Is. *Cp.*

Family *Loligidæ.*

490. *Ommastrephes giganteus,* D'Orb. Peru. Common at S. Clemente Is. *Cp.*
491. *Ommastrephes Ayresii,* Gabb, Proc. Cal. Ac. Hundreds on S. Clemente Is. *Cp.*
492. *Onychoteuthis fusiformis,* Gabb, Proc. Cal. Ac. 1862, p. 171. "Cape Horn, Mus. Ac." S. Clemente Is. *Cp.*

113. It remains to tabulate the shells which have been received from special localities, south of the State of California, either by the writer or by the Smithsonian Institution; *vide* Br. Assoc. Rep., par. 77.

The promontory of Lower California has been so little explored, that the existence of a large inland fiord, in lat. 28°, was not known to the authorities. It appears that the whales have long delighted in its quiet waters; and those whalers who were in the secret carefully preserved the exclusive knowledge of so profitable a hunting-ground. All that we know at present of the molluscs of that region is from collections made at Cerros Island, by Dr. Ayres and Dr. Veitsch. They are mostly shore shells, and are sadly intermixed with an abundance of cowries, cones, strombs, and other clearly Pacific species, which throw great doubt upon those which may be truly from the coast. As it is manifestly a "hotbed of spurious species," nothing can safely be built upon the data, which present a singular intermixture of northern and southern forms. Excluding the Central Pacific importations, the lists stand as follows, the temperate species being distinguished (as in the first Report) by a *, the tropical by a †:—

*Sanguinolaria Nuttalli.
*Macoma secta.
Angulus Gouldii.
*†Heterodonax bimaculatus.
*Donax Californicus.
†Donax punctatostriatus.
*Standella ?Californica.
*Pachydesma crassatelloides.
*†Amiantis callosa.
*Chione simillima.
†Chione neglecta.
*Tapes staminea, *Conr.*
†Tapes grata and vars.
*Lucina Californica.
Lucina bella.
*Mytilus edulis. (One young specimen, perhaps from San Francisco.)
*Septifer bifurcatus.
†Pecten subnodosus, ventricosus.
*Pecten monotimeris and vars.
*Hinnites giganteus.
*†Ostrea conchaphila.
*†Anomia ?lampe.
Siphonaria æquilirata.
*†Melampus olivaceus.
Helix arrosa.
*†Bulla nebulosa.
*†Ischnochiton Magdalensis.
*Acmæa persona, *var.* textilis.
*Acmæa scabra, *var.* limatula.
*Acmæa ?spectrum, jun.
*Lottia gigantea.
*Lucapina crenulata.
*Fissurella volcano.
*Haliotis splendens.
*Haliotis Cracherodii.
*Pomaulax undosus.
Callopoma tessellatum = Fokkesii.
*Trochiscus Norrisii.
*Omphalius ?fuscescens.
*Omphalius aureotinctus.
†Crucibulum imbricatum.
*†Crucibulum spinosum.
†Crepidula arenata and var.
†Cerithium uncinatum.
*Cerithidea pullata.
†Cerithidea Montagnei.
*Litorina planaxis.
Luponia sp. ind., jun.
†Trivia Solandri.
*Trivia Californica.
Drillia penicillata.
Myurella, sp.
*†Neverita Recluziana.
†Natica Maroccana.
*Scalaria (Ind. var.) tincta.
†Bezoardica abbreviata.
†Leucozonia cingulata.
†Strigatella tristis.
*Olivella biplicata.
*Purpura ostrina, vars.
†Purpura biserialis.
Monoceros lugubre.
†Vitularia salebrosa.
Cerostoma monoceros.
Ocinebra Poulsoni.
Chorus Belcheri.
†Columbella fuscata.
*Columbella carinata.
†Strombina gibberula.
†Anachis coronata.
*†Nassa tegula.
†Nassa complanata.
Macron Kellettii.
*Macron lividus.

The shells of Margarita Bay, on the Pacific coast of Lower California, in lat. 24°, have become known through W. Harper Pease, Esq., of Honolulu, Sandwich Islands. Through his labours we are likely soon to be favoured with accurate accounts of the distribution of species in the various parts of the Pacific Ocean. Already his researches have greatly enriched our knowledge of the quaint fauna of the Sandwich Islands, from which he has eliminated the spurious species, and added those erroneously ascribed to California by previous naturalists. The principal trade from these islands is with San Francisco; and "the coast," in Mr. Pease's writings, signifies the coast of California or (generally) of Western America. Many of our best specimens of rare West-coast shells have been received from him, and in remarkably fresh preservation. The Margarita Bay species were obtained by one of his trained collectors, and are as follows:—

Martesia intercalata.
Saxicava pholadis
Solecurtus violascens.
Hiatula compacta.
*Tellina secta.
Strigilla carnaria (pink).
Semele Californica.
Donax punctatostriatus.
Dosinia ponderosa.
Callista chionæa.
Callista vulnerata (? = tricolor, *Pse.*).
Chione succincta
Chione gnidia.
Tapes grata.

*Tapes staminea.
Chama frondosa.
Cardium procerum.
Liocardium elatum.
Modiola capax.
Modiola Brasiliensis.
Lithophagus attenuatus.
Barbatia gradata.
Pecten ventricosus.
Ostrea Virginica (Maz. Cat.).
*Ostrea lurida, *var.*
Ostrea conchaphila.
Ostrea amara.
Siphonaria æquilirata (=leviuscula, *Sby.*, teste *Cuming*).
Siphonaria gigas.
*Helix areolata, *Fbs.* (The only land-shell received from the Bay.)
Dentalium tetragonum, *Sby.*
Dentalium semipolitum.
Dentalium lacteum, *Phil.*
Acmæa strigatella.
Acmæa atrata.
Gadinia reticulata.
Calliostoma versicolor.
*Chlorostoma gallina.
*Chlorostoma aureotinctum.
Nerita scabricosta.
Nerita Bernhardi.
Crucibulum spinosum.
Crucibulum imbricatum.
Crepidula onyx.
Crepidula excavata.
Galerus conicus.
Cerithium stercus muscarum.
Pyrazus incisus and var.
Rhinoclavis gemmata.
Cerithidea Mazatlanica.
Litorina fasciata.
Litorina aspera, var.
Conus "reticulatus" (*Pease*). Dead.
Conus "emarginatus" (*Pease*). Dead.
Conus interruptus.
Neverita Recluziana.
Polinices bifasciata.
Cancellaria urceolata.
Cancellaria goniostoma.
"Cypræcassis testiculus" [perhaps *tenuis*].
Malea ringens.
Priene nodosa.
Oliva subangulata.
Oliva porphyria.
Purpura patula.
Purpura biserialis.
*Purpura ostrina. [Normal, living.]
Vitularia salebrosa.
Monoceros lugubre, var.
Cerostoma monoceros.
Nassa tegula.
Siphonalia anomala.
Phyllonotus nigritus.

In the above list, the only strictly Californian species are those marked with a *.

The following species have been received from La Paz, besides those tabulated in Major Rich's list, p. 541, in the C. S. L. list, p. 619, and the B. A. Rep. p. 352. It is clear that the fauna of the district is essentially tropical, and remarkably free from Californian species.

Dentalium semipolitum.
Turritella punctata.
Modulus cerodes.
Olivella fulgida, Lieut. Trowbridge [teste W. Cooper; but probably added by him accidentally from his W. African collections. It has not been received from any other West-coast source].
Siphonalia modificata. Dead.

A very interesting series of shells were collected at Guaymas and Pinacati Bay, by Capt. Stone and Mr. Sloat. The latter gentleman affixed MS. names to those which he regarded as new. They were in remarkably beautiful condition, the bivalves having an unusually porcellanous aspect, and many of the species presenting local peculiarities.

Mulinia carinulata, Desh.,= *Mactra modesta*, Sloat MS.
Dosinia ponderosa. Very large.
Chione fluctifraga, Sby.,= *V. Cortezi*, Sloat MS. [=*gibbosula* (Desh.), Rve.,= *callosa*, Sby., non Conr.].
Chione succincta, Val.,= *Californiensis*, Brod.,= *V. crassa*, Sloat MS. [Very variable in sculpture; also, with the last, varies greatly in shape, some of the specimens being much produced, others rounded.]
Chione gnidia, Brod. Passing into *amathusia*.

Chione pulicaria, Sby., var.,= *V. Pinacatensis*, Sloat MS. Sculpture pressed smooth in the middle.
Cardium elatum. Fine.
Cardium procerum. Fine.
Modiola capax. "Choros." Also Sta. Iñez Bay.
Modiola Brasiliensis. (Typical.)
Byssoarca Pacifica.
Ostrea conchaphila et *amara*, Maz. Cat. 215.
Chiton (*Lophyrus*) *Stokesii.* Also San Salvador, *Capt. Dow.*
Callopoma fluctuatum.
Bivonia contorta.
Turritella goniostoma.
Turritella tigrina (light var.),=*leucostoma*, Val.
Cerithidea albonodosa. Common. [Probably a var. of *Mazatlanica.*]
Strombus gracilior. Also Mulege Bay.
Neverita Recluziana. [Operc. strong, horny.]
Ranella triquetra. [Operc. sub-Buccinoid, oval; nucleus internal, near middle of labrum; scar with few ridges, as in *Purpura.*]
Oliva angulata. Not rare.
Oliva Cumingii, very callous var.
Agaronia testacea.
Monoceros lugubre. Very tall var.
Phyllonotus nigritus. Very large, of form described by Philippi, with Pholads *in situ.* Agiobampo Bay.
Phyllonotus bicolor. [Operc. thin, without frills or raised layers; of uniform colour.] Also Angeles Bay.

To these may be added, from a second voyage by Capt. Stone to the northern part of the Gulf of California, and in equally good condition—

Arca grandis. Agiobampo Bay.
Callista semilamellosa. Agiobampo Bay.
Lazaria pectunculus (teste Cuming). St. Luis Bay.
Cardium consors. St. Luis Bay.
Avicula Peruviana. Mulege Bay.
Lucina tigerrina. Very fine. San Marcos Island.
Margaritiphora fimbriata. "Topo."
Janira dentata [=*excavata*, Val.]. "Caballito del mar," St. Luis Bay.
Bulla nebulosa. "Huevitos."
Glyphis inæqualis. St. Luis Bay.
Crucibulum imbricatum. St. Luis Bay.
Cypræa exanthema. (Large.) Cape de Haro.
Myurella variegata. Mulege Bay.
Solarium granulatum et var. *quadriceps.* Agiobampo Bay.
Polinices bifasciata. Angeles Bay.
Cypræcassis tenuis [= *Marsenæ*, Kien.]. Carmen Island.
Harpa crenata. Very fine. Mulege Bay.
Bezoardica abbreviata. Mulege Bay.
Ficula decussata. Angeles Bay.
Pyrula patula. Agiobampo Bay.
Malea ringens. Lobos Island.
Argonauta hians. 1 fine sp. Upper part of Gulf of California.

To the Guaymas fauna must be added, from Dr. Gould's portion of the same collection, "*Pecten pyxidatus*" [?=*subcrenatus*, jun.). Also from the collection of the Calif. Ac. Nat. Sc., *Nassa nodocincta*, A. Ad. [Galapagos, *Cuming*]. On comparing these lists with the shells given in B. A. Rep. p. 352 (in which the *Venus* quoted is not "*staminea*, Conr.," but a southern species), it will be seen that the fauna of the upper part of the Gulf, as far north as it has been explored, is essentially tropical. The *Chione fluctifraga*

and *C. succincta*, however, and the *Polinices Recluziana* indicate a connexion with California which may have been, at a previous age, more direct than at present.

114. (See first Report, pars. 79–83.) Acapulco being notorious for the exotic species quoted in its fauna, it is desirable to examine all authentic collections from that prolific locality. The Smithsonian series were obtained by Dr. Newberry * (*N.*), after his Pacific R. R. Explorations (*vide* p. 593); by Mr. Belcher (*B.*); and by the Rev. J. Rowell (*R.*), who obtained them principally from the valves of the large oysters. The private collections of Judge Cooper, Col. Jewett (*J.*), and other American naturalists have also afforded valuable information. The species from these various sources, which were also found by Mr. Xantus, are tabulated with his Cape St. Lucas series, *anteà*, pp. 619–626. The following have not been obtained from the northern localities:—

Corbula nuciformis, *J.*
Corbula ovulata, and smooth var., *B.*, *J.*
Machæra patula, var., *N.* [Surely imported.]
Sanguinolaria miniata, *J.*, *N.*, *B.*
Tellina princeps, *B.*; punicea, *N.*, *B.*; opercularis, *N.*
Strigilla carnaria, pale and crimson vars., *N.*, *B.*
Semele proxima, *J.*; pulchra, *J.*, *N.*; venusta, *J.*
Donax carinatus, *J.*, *N.*; rostratus, *J.*; transversus, *N.*
Trigona Hindsii, *J.*
Mactrella carinata, *Lam.*, = alata, *Spengl.*, *N.* [Perhaps imported.]
Dosinia Annæ, *N.*
Callista circinata, *J.*; semilamellosa, *N.*, *B.*; spinosissima, *B.*
Chione amathusia, *N.*
Rupellaria foliacea, *R.*
Petricola ventricosa, *R.*
Chama corrugata, *R.*
Cardium ?aculeatum, jun., *N.* [probably from ballast]; graniferum, *N.*
Lucina ?pectinata, var., *J.* [More like *imbricatula*, W. I.; perhaps Jamaican.]
Diplodonta semiaspera, *R.*
Felania tellinoides, var., *J.* [More like *subglobosa*, W. I.; perhaps Jamaican.]
Corbicula ?convexa, 1 worn valve, *N.*
Scapharca bifrons, *N.*; labiata, *B.*
Noëtia reversa, *J.*, *B.*
Argina brevifrons, *N.*
Axinæa parcipicta [= multicostata], *J.*, *N.*; pectenoides, *J.*; inæqualis, *J.*
Lima angulata, *J.*
Ostrea megodon [P.Z.S. 1845, p. 106], *N.*
Anomia lampe, *J.*
Tornatina infrequens, *B.*
Dentalium ?hexagonum, var., *B.*
Fissurella nigropunctata, *J.*; ?macrotrema, *J.*; alba, jun., *B.* (1 worn sp.)
Calliostoma lima, *var.* æquisculpta, *N.*; Leanum, *J.*
Senectus squamigerus, *J.*
Galerus conicus, *N.*; mamillaris, *N.*
Crepidula nivea, *R.*; incurva, *N.*
Turritella Banksii, *N.*; leucostoma, *B.*
Ampullaria Columbiensis, *R.* [West Mexico; locality uncertain.]
Truncatella Bairdiana, *B.*
Radius avena, *J.*
Cypræa exanthema, *N.*
Luponia fimbriolata, *Beck*, *N.* [Probably imported, and perhaps an imperfectly developed form of *semipolita*, Migh.]
Terebra tuberculosa, *N.*
Drillia incrassata, *B.*; eburnea, n. s., *R.* [W. Mexico; locality uncertain.]
Mangelia subdiaphana, *J.*
Conus interruptus, *Br. & Sby.*, *B.*; mahogani, *N.*; puncticulatus, *N.*
Eulima hastata, *R.*
Eulima, *like* yod, *R.*
Eulimella, sp. (worn), *B.*
Chemnitzia tenuilirata, *B.*
Fasciolaria, sp. [size of *tulipa*, but with row of knobs and serrated lip], *N.*
Latirus castaneus, *N.*
Volvarina ?fusca, *J.* [More regularly cylindrical than the W. I. specimens, broader in proportion near suture and at base, spire much shorter; but locality uncertain.]
Oliva Julietta, *B.* 1 worn sp. [probably imported]; ?kaleontina, dead, *N.*

* The collections of Dr. Newberry passed principally into the hands of Dr. E. Foreman, late of Washington, who kindly presented a series to the Mus. Smiths. After the secession-movement, he went into the Confederate States, where it was not possible to obtain further information from him.

Agaronia testacea, *N.*
Rhizocheilus madreporarum. 2 living sp. on coral, *J.*
Columbella uncinata, *J.*; humerosa, n. s., *R.*; varians, var., *N.* [?Imported from Sandw. Is.]
Nassa collaria, *N.*; ambigua, *Mont.*, teste *Hanl.*, *N.* [Probably imported from W. I.]
Anachis coronata, *N.*; Californica, *J.*
Muricidea alveata, *J.*
Phyllonotus brassica, *N.*

The following species are part of a collection received at the Smithsonian Inst. from Real Llejos, and fill up gaps which existed in the Central American fauna at the time of the first Report:—

Discina Cumingii.
Trigona Hindsii.
Hemicardium obovale.
Crassatella gibbosa.
Kellia suborbicularis.
Barbatia mutabilis.
Noëtia reversa.
Axinæa ?multicostata.
Fissurella rugosa.
Phasianella perforata.
Omphalius viridulus.
Hipponyx barbatus.
Cæcum liratocinctum.
Cæcum læve.
Cerithium interruptum, var.
Barleeia subtenuis.
Aricia punctulata.
Terebra strigata.
Cerithiopsis assimilata.
Triforis alternata.
Olivella gracilis.
?Nitidella millepunctata.
Northia pristis.
Pisania sanguinolenta.

The collections received at the Smithsonian Inst. from Panama consist, in the main, of species already tabulated from that region. The following, however, are new to that well-searched portion of the fauna:—

Tellina striata (teste Cuming), Rowell, Pease.
Tellina (*Angulus*) *amplectans*, n. s., Rowell, Pease.
Adula stylina. } Californian species: either ballast or error in numbering: *Rowell.*
Pecten æquisulcatus, jun. }
Litorina. Small spotted species, n. s., teste *Cuming*, but appears identical with the W. Indian: probably imported: *Rowell.*
Fluminicola, sp., Rowell.
Drillia albolaqueata, n. s., Rowell.
Natica catenata, Rowell.
Cuma costata, Rowell.

115. The Pulmonates of the Pacific slope have not formed a special study with the writer of this Report, as they were already in the abler hands of Messrs. Binney, Bland, and other eminent Transatlantic naturalists. The opinions of Mr. Binney as to synonymy, &c., with descriptions of new species and details of those previously known, were given in papers published in the 'Proc. Ac. Nat. Sc. Phil.' as follows:—"Descriptions of American Land Shells," Feb. 1857; "Notes on American Land Shells," Oct. 1857, May 1858, Nov. 1858, July 1859: and also in the 'Proc. Bost. N. H. S.,' "Description of two supposed new species of American Land Shells," Apr. 1857. These are embodied in 'The Terrestrial Air-Breathing Molluscs of the United States and the adjacent Territories of North America,' vol. iv., by W. G. Binney, Boston, 1859. It was first printed in the 'Boston Journal of Natural History,' vol. vii., and is intended as a Supplement to the great treatise by his father, vols. i.–iii., on the same subject. It is impossible to speak in too high terms of commendation of the manner in which this work has been prepared and executed, and of the beautiful figures drawn by Otto Köhler. The more matured views of the author were embodied in the 'Check-List of the Terrestrial Gasteropoda of North America,' published by the Smithsonian Inst., June 1860, of which a second edition was soon issued. The species were divided into three series,—(1) those of the Pacific coast,

from the extreme north to Mazatlan; (2) those of eastern N. A., from the boreal regions to the Rio Grande; (3) those found in Mexico, to which sixteen from the first series are added. The freshwater Pulmonates are catalogued by the same most industrious author, in the 'Check-List of the Fluviatile Gasteropoda of N. America,' which contains the *Melaniadæ*, *Paludinidæ*, *Ampullariadæ*, *Valvatidæ*, and *Limnæidæ*; the West Coast species being distinguished by the letter **W**, and the Mexican by **M**. Mr. Binney next undertook a monograph of the *Paludinidæ*, &c., the proofs of which were widely distributed in 1862. Afterwards, assisted by the extensive series of specimens received from the Smithsonian Museum, and with access to those of the principal public and private collections in the U. S., and with the benefit of Say's types preserved in the Acad. Nat. Sc. Phil., he prepared a preliminary synopsis of the *Limnæidæ*, with full synonymy, proofs of which were issued by the Smithsonian Inst., May 4th, 1863. Last of all, under date Dec. 9, 1863, the Smithsonian Inst. has distributed proof copies of a complete 'Synopsis of the Species of Air-Breathing Molluscs of N. A., as eliminated from their synonyms by Mr. Binney'*. Of all these works the author not only sent the earliest slip-proofs to assist in the preparation of this Report, but in several instances took the pains to write separately what related to the W. coast, and even sent the manifold-duplicate of part of the printer's copy. It is not considered necessary to tabulate each of these publications separately, as they can easily be obtained by post, on application to Professor Henry, Washington, D.C. The following list embodies—(1) the classification and nomenclature of Dec. 9th, 1863; (2) the synonymy as given in previous synopses; and (3) the localities and authorities supplied by Mr. Binney in MS. The following reservation requires attention:—"As a mere proof, which will undoubtedly receive many corrections, this list should not be quoted as authority, or referred-to as a published work."

Mr. Binney's Arrangement of the West Coast Pulmonates.

† The species thus marked have not been seen by Mr. Binney.

PHANEROPNEUMONA.

ECTOPHTHALMA. (None known in the region.)

OPISTHOPHTHALMA. Fam. *Truncatellidæ*.

1. *Truncatella Californica*, Pfr., + *T. gracilenta*, Gld. S. Diego, *Cooper*. [Comp. Maz. Cat. no. 423.]

PULMONATA.

GEOPHILA. § 1. *Vermivora*. Fam. *Oleacinidæ*.

†2. *Glandina* (*Glandina*) *turris*, Pfr. (= *Achatina* = *Oleacina*, Pfr.) W. Mexico. Maz. Cat. no. 231.

3. *Glandina* (*Glandina*) *Albersi*, Pfr. (= *Achatina*, Pfr.)., + *G. Albersi*, var. *turrita*, Cpr. W. Mexico. Maz. Cat. no. 230.

* The first Transatlantic attempt to revise the genera of N. A. *Helicidæ* was made by Mr. Bland, in his "Remarks on Classifications of N. A. *Helices* by European authors, and especially H. and A. Adams and Albers," printed in the 'Annals of the Lyceum of Nat. Hist. N. York,' Oct. 1863. In an addendum, he gives a list of the Pacific species, with an account of two "genera" not represented in the eastern division. Mr. Binney, continuing Mr. Bland's labours, issues the species for the most part in the trinomial nomenclature, which now appears to be taking the place of the Linnean binomial system. No attempt is here made to review the work, as the writer felt justified in doing with reference to marine shells; the only alterations made consisting of corrections in some of the citations with which he happened to be more familiar.

§ 2. *Phyllovora.* Fam. *Helicidæ.*

Subfam. *Vitrininæ.*

†4. *Vitrina Pfeifferi,* Newc. Carson Valley, Cal., *Newcomb.*
5. *Binneya notabilis,* Cp. Catalina Island, Cal., *Cooper.*
6. *Macrocyclis Newberryana,* Bin. S. Diego, common, *Newberry.*
7. *Macrocyclis Vancouverensis,* Lea, *Helix V.,* Lea, Trosch., Pfr., Gld., Rve.,= *H. vellicata,* Fbs., Rve., Pfr., + *H. concava.* Binn. VANCOUVER TO CALIFORNIA :—Columbia R., *Nuttall, U. S. E. E.*; Puget Sound, *U. S. E. E.*; Vancouver, *B. N. P. B. S.*; Oregon City, *Newberry*; California, *Trowbridge*; St. Joseph's R., 2nd Camp.
7*b*. *Macrocyclis* [?var.] *sportella**, Gld. PUGET SD. TO S. DIEGO :—Puget Sd., *U. S. E. E.*; Fort Umpqua, Oregon; S. Diego, *Ives, Newberry*; S. Francisco, Mus. Cal. Ac.; Contra Costa Co., *Thomson.* "Animal solitary."

Subfam. *Helicinæ.*

8. *Helix* (*Patula*) *strigosa,* Gld. INTERIOR BASIN; N. MEXICO TO BRIT. AM.: —Int. of Oregon, *U. S. E. E.*; Cañon Largo, Rio Pedro, N. M., *Newberry.*
9. *Helix* (*Patula*) *Cooperi,* Bin. California.
10. *Helix* (*Patula*) *Mazatlanica,* Pfr. Mazatlan.
11. *Helix* (*Polygyra*) *acutedentata,* Bin.,+*H. Loisa,* Bin. Guaymas. Mazatlan, *Gambel.*
12. *Helix* (*Polygyra*) *ventrosula,* Pfr. [No locality given: not "**w.**" in Check-Lists.]
13. *Helix* (*Polygyra*) *polygyrella,* Bland. "**w.**" [teste Check-List, not in MS.]
14. *Helix* (*Stenotrema*) *germana,* Gld. Oregon, *U. S. E. E.*
15. *Helix* (*Triodopsis*) *Mullani,* Bland. WASHINGTON TERRITORY AND OREGON: —St. Joseph's River, 1st Camp.
16. *Helix* (*Triodopsis*) *loricata,* Gld., Pfr., = *H. Lecontei,* Lea. Sacramento River, *U. S. E. E.*
17. *Helix* (*Mesodon*) *Columbiana,* Lea, Trosch., Rve., Pfr.,+*H. labiosa,* Gld., Pfr. VANCOUVER TO OREGON :—Ft. Vancouver, *Nuttall*; Ft. George, *U. S. E. E.*; Nootka Sound, *Hinds*; Astoria, *Drayton*; Oregon City, *Newberry.*
18. *Helix* (*Mesodon*) *devia,* Gld., Pfr., =*H. Baskervillei,* Pfr., Rve. Puget Sound, *U. S. E. E.*; Oregon.
19. *Helix* (*Aglaia*) *fidelis,* Gray, Müll., Rve., Pfr., = *H. Nuttalliana,* Rve., Trosch., Gld. VANCOUVER TO OREGON :—Puget Sound, Columbia River, *U. S. E. E.*; Esquimault Harb., *Lord*; Umpqua Valley, Or., and San Francisco, *Newberry*; De Fuca, *Gibbs*; Oregon City, *Shumard*; Ft. Steilacoom, *Suckley.*
20. *Helix* (*Aglaia*) *infumata,* Gld. San Francisco, *Bigelow.*
21. *Helix* (*Arianta*) *arrosa,* Gld., =*H. æruginosa,* Gld. (nom. preoc.). OREGON, CALIFORNIA :—San Francisco, *Bigelow, Samuels*; Petaluma and Columbia River, *Newberry.*
22. *Helix* (*Arianta*) *Townsendiana,* Lea, Trosch., Rve., Pfr., Gld.,+*H. pedestris* +*ruida,* Gld. OREGON AND CALIFORNIA :—Wahlamat River, *Nuttall, Townsend, U. S. E. E.*; Nisqually, *Dyes.*; Puget Sound, *Kennerley.*
23. *Helix* (*Arianta*) *tudiculata,* Binn. WASHINGTON TERRITORY TO CALIFORNIA: —San Diego, *Newberry.*
24. *Helix* (*Arianta*) *Nickliniana,* Lea, = *H. Californiensis,* Rve., Pfr. (non Lea), = *H. arboretorum* + *nemorivaga,* Val.—Var. = *H. anachoreta,* Binn. "Widely distributed, but solitary," *Thompson.* CALIFORNIA :—Sacramento River, *U. S. E. E.*; San Francisco, *Bigelow*; Tomales, *Newberry.*
25. *Helix* (*Arianta*) *redimita,* Binn. (jun.), = *H. Nickliniana,* var. Binn. (sen.). California.

* In the Check-List of Dec. 9th, *sportella* does not appear. It is generally treated by Mr. Binney as a small variety of *Vancouverensis,* with stronger radiating and spiral lines; but in the MSS. sent for publication in this Report it takes rank as a species. Mr. Bland considers the two identical; yet in Add. Gen. the form is thus divided:—"*Iberus* (*Campylæa*) *sportella,* in fam. *Helicidæ,*" and "*Discus Vancouverensis,* in fam. *Stenopidæ.*" In Albers it is divided as "*Macrocyclis vellicata,*" "*M. Vancouverensis,*" and "*Helix* (*Patula*) *sportella.*"

26. *Helix* (*Arianta*) *intercisa*, Binn. (jun.),=*H. Nickliniana*, var. Binn. (sen.). Oregon.
†27. *Helix* (*Arianta*) *exarata*, Pfr. California.
†28. *Helix* (*Arianta*) *reticulata*, Pfr. California.
†29. *Helix* (*Arianta*) *ramentosa*, Gld. California, *Newcomb.*
†30. *Helix* (*Arianta*) *Ayresiana*, Newc. Northern Oregon.
†31. *Helix* (*Arianta*) *Bridgesii*, Newc. San Pablo, California, *Newcomb.*
†32. *Helix* (*Arianta*) *Carpenteri*, Newc. Tulare Valley, California. [Not *Carpenteriana*, Bland; Florida.]
33. *Helix* (*Arianta*) *Californiensis*, Lea, Trosch., Dekay (non auct.),=*H. vincta*, Val., Rve., Pfr. CALIFORNIA:—Interior of Cal, *U. S. E. E.*; Monterey, *Ives.*
†34. *Helix* (*Arianta*) *Mormonum*, Pfr. Mormon Is., California.
35. *Helix* (*Arianta*) *Dupetithouarsi*, Desh., Rve., Pfr., + *H. Oregonensis*, Trosch., Dekay, Pfr. WASHINGTON TERRITORY TO CALIFORNIA. Interior of Cal., *U. S. E. E.*; Puget Sound, *Dyes.*; Klamath Lake and Benicia, *Newberry*; Tulan Lake, Cal.; Monterey, *Trowbridge*; San Diego, *Ives.*
†36. *Helix* (*Arianta*) *Traskii*, Newc. Los Angelos, California, *Newcomb.*
37. *Helix* (*Arianta*) *Kellettii*, Fbs., Rve., Pfr. Sta. Barbara, *Kellett* and *Wood*; San Diego, teste Gould.
38. *Helix* (*Arianta*) *Pandoræ*, Fbs., Rve., Pfr.,=*H. damascenus*, Gld. Sta. Barbara, *Kellett* and *Wood*; Desert East of California, Mus. Newcomb.
39. *Helix* (*Arianta*) *levis*, Pfr.,+var. β. Columbia River.
40. *Helix* (*Euparypha*) *areolata*, Sby., Pfr., Phil., Rve.,+vars. β. γ. PENINSULA OF LOWER CALIFORNIA. [Margarita Bay, *Pease.**]
†41. *Columna* (*Rhodea*) *Californica*, Pfr. [*Achatina*, Pfr., Rve.]

Subfam. *Orthalicinæ.*

42. *Bulimulus* (*Liostracus* [not *Leiostraca*, Add.]) *Ziegleri*, Pfr. Mazatlan, *Reigen.*
[†43. *Bulimulus Mexicanus* ‡, Lam., Deless., Pfr., Rve. (non Val.),= *Cochlogena vittata*, Fér. Mazatlan, *Reigen.*]
44. *Bulimulus* (*Mesembrinus*) *pallidior*, Sby.,=*B. vegetus*, Gld., teste Cum., Binn. SAN DIEGO TO CAPE ST. LUCAS:—C. S. Lucas, *Xantus.*
45. *Bulimulus* (*Mesembrinus*) *excelsus*, Gld. (text),=*B. elatus*, Gld. (fig.). SAN DIEGO TO CAPE ST. LUCAS:—C. S. Lucas, *Xantus.*
46. *Bulimulus* (*Mesembrinus*) *inscendens*, Binn. LOWER CALIFORNIA:—Margarita Bay, and C. S. Lucas, *Xantus.*
†47. *Bulimulus* (*Thaumastus*) *Californicus*, Rve.
†48. *Bulimulus* (? *Mormus*) *sufflatus*, Gld.,=*B. vesicalis*, Gld. (nom. preoc.). LOWER CALIFORNIA.
49. *Bulimulus* (? *Mormus*) *pilula*, Binn. LOWER CALIFORNIA:—Todos Santos Mission, Margarita Is., *Xantus.*
50. *Bulimulus* (*Scutalus*) *proteus*, Brod. Cape St. Lucas, *Xantus.*
51. *Bulimulus* (*Scutalus*) *Xantusi*, Binn. Cape St. Lucas, *Xantus.*
52. *Bulimulus* (*Peronæus* [non *Peronæa*, Poli]) *artemisia*, Binn. Cape St. Lucas, *Xantus.*
53. *Orthalicus* (*Orthalicus*) *zebra*, Müll., Pfr. Mazatlan, *Reigen.* } Also Eastern slope.
53*b*. *Orthalicus* (*Orthalicus*) *undatus*, Fér., Pfr. § "Mazatlan." }

Subfam. *Pupinæ.*

†54. *Pupa* (*Pupilla*) *Rowellii*, Newc. San Francisco, *Rowell.*
†55. *Pupa* (*Pupilla*) *Californica*, Row. San Francisco, *Rowell.*
56. *Pupa* (*Leucochila*) *chordata*, Pfr. Cinaloa, Mexico.

* See also Dr. Newcomb's new species, tabulated in pp. 609, 633.

‡ Included among the doubtful species by Mr. Binney; but the shell so named in the Maz. Cat., no. 234 (perhaps erroneously), was certainly found on opening the Mazatlan boxes by Mr. Archer.

§ Mr. Binney follows Pfr., in his later works, in separating these ? varieties. The shells in the Reigen Collection were clearly conspecific. *Vide* Maz. Cat., no. 232.

Subfam. *Succininæ.*

†57. *Succinea* * (*Succinea*) *Hawkinsi*, Baird. British Columbia, *Lord.*
†58. *Succinea* (*Succinea*) *cingulata*, Fbs. Mazatlan, *Kellett* and *Wood.*
59. *Succinea* (*Succinea*) *rusticana*, Gld. OREGON AND CALIFORNIA:—Oregon, *U. S. E. E.*; Ocogo Creek, California, *Williamson.*
60. *Succinea* (*Succinea*) *Nuttalliana*, Lea. "Scarcely differs from *S. ovalis*, Hudson River," *Gld.* OREGON AND CALIFORNIA:—Lewis's River, Or., *Nuttall*; Interior of Oreg., *U. S. E. E.*; Wright's Lake, Rhell's Lake, Cal., *Newberry.*
61. *Succinea* (*Succinea*) *Oregonensis*, Lea. "Resembles *S. aurea*," Gld. OREGON AND CALIFORNIA:—Oregon, *Nuttall.* San Francisco, *Rowell.*

Subfam. *Limacinæ.*

62. *Limax* ‡ (*Amalia*) *Columbianus*, Gld. PUGET SOUND TO SAN FRANCISCO:—Puget Sound, *U. S. E. E.*, *Dyes*; Oregon City and Cape Flattery, *Williamson*; San Francisco and Port Oxford, *Trowbridge*; Nisqually, *Case.*

Fam. *Arionidæ.*

Subfam. *Arioninæ.*

63. *Arion* (*Lochea*) *foliolatus*, Gld. Puget Sound, *U. S. E. E.*, *Pickering.*

Subfam. *Zonitinæ.*

64. *Zonites* § (*Ægopis*) *cultellata*, Thoms. "Closely resembles the Dalmatian *H. albanica* and *acies*." Contra Costa Co., Cal., common, *Thomson.*

Fam. *Onchidiadæ.*

65. *Onchidium Carpenteri*, Binn. Cape St. Lucas, *Xantus.*

LIMNOPHILA. Fam. *Auriculidæ.*

Subfam. *Melampinæ.*

66. *Melampus olivaceus*, Cpr. SAN DIEGO TO MAZATLAN:—Mazatlan, *Reigen*; San Diego, *Blake*, *Cooper.*
67. *Pedipes lirata*, Binn. LOWER CALIFORNIA:—C. S. Lucas, *Xantus*; San Diego, *Cooper.*

Fam. *Limnæidæ.*

Subfam. *Limnæinæ.*

68. *Limnæa* (*Limnæa*) *stagnalis*, Linn., + *L. jugularis*, Say, Hald., De Kay, Küst., Binn. (1st list), + *L. appressa*, Say, Hald., De Kay, Küst., C. B. Ad., + *L. speciosa*, Ziegl. EUROPE, ASIA, AMERICA:—Rhett Lake, California, *Newberry*; Ruby Valley and S. Utah, *Captain Simpson.* Fort Simpson and Hudson's Bay, common; throughout British America and northern tier of U. S., from Vermont to Pacific, teste Binn. [Var. = *H. fragilis*, Linn., teste Hanl., Ips. Linn. Conch. p. 385; non Rve., Binn. (1st list).]
69. *Limnæa* (*Limnæa*) *lepida*, Gld. Lake Vancouver, *U. S. E. E.*
70. *Limnæa* (*Limnophysa*) *reflexa*, Say, Hald., De Kay, Küst., + *L. elongata*, Say, *L. umbrosa*, Say, Hald., De Kay, Küst., + *L. exilis* + *L. Haydeni*, Lea. San Francisco, *Rowell.* Also through British America and northern tier of States from New York to Pacific; teste Binn.
†71. *Limnæa* (*Limnophysa*) *Sumassii*, Baird ||.

* So great is the difficulty of ascertaining (even approximately) the specific relations of *Succineæ* without a comparison at least of single specimens, that Mr. Binney considers it safest, until series have been examined, simply to quote the species which have been described by other authors. He has followed the same course with *Ancylus*, and for the same reason.

‡ "Has a pore. Why not *Arion*?"—*Binney*, in MS. list.

§ This appears among "doubtful species" in the MS., but is printed in the text of the Check-List.

|| Probably a variety of *palustris* = *Nuttalliana*, Lea. British authors have as yet had but poor opportunities of studying typically-named American freshwater Pulmonates,

72. *Limnæa* (*Limnophysa*) *palustris*, Müll. et auct.,=*L. fragilis* (as of Linn.), Hald., De Kay, Binn. (1st list), Rve. (hodie). [Non Linn., teste Hanl. in Ips. Linn. Conch., p. 385]. +*L. elodes*, Say, Gld., C. B. Ad., Küst.,+*L. Nuttalliana*, Lea, Küst., ?+*L. plebeia*, Gld.,+*L. expansa*, Hald., De Kay, Küst. NORTHERN EUROPE, ASIA, AND AMERICA:—Columbia River, *Nuttall*; Puget Sound, *Kennerley*; Klamath Lake and Summer Lake, Or.; Rhett Lake and Wright's Lake, Cal., *Newberry*: Clear Lake, Cal., *Veatch*; San Francisco, *Rowell*; Monterey, *Canfield*; Porcupine and Yuckron Rivers, Rus. America, *Kennicott*. Also from Pennsylvania westward to Pacific, and from this line northwards, wherever searched, even to interior of Russian America; teste Binn.

73. *Limnæa* (*Limnophysa*) *proxima*, Lea. San Francisco, *Cooper*. Arroya San Antonio, *Trask*.

74. *Limnæa* (*Limnophysa*) *emarginata*, Say, Hald., De Kay, Küst.,=*L. Ontariensis*, Muhlf., Küst.,+*L. serrata*, Hald. NEW ENGLAND TO WASHINGTON TERRITORY.

75. *Limnæa* (*Limnophysa*) *catascopium*, Say, Hald., Gld., De Kay, Mrs. Gray, Pot. & Mich., Küst.,+*L. pinguis*, Say (non Dohrn), =*L. Virginiana*, Lam., Desh., Deless., =*L. cornea*, Val., =*L. sericata*, Ziegl. NEW ENGLAND TO LEWIS RIVER, AND THROUGH BRITISH AMERICA; teste Binn.

76. *Limnæa* (*Limnophysa*) *Adelinæ*, Tryon. San Francisco.

77. *Limnæa* (*Limnophysa*) *Traskii*, Tryon. Mountain Lake, California.

78. *Limnæa* (*Limnophysa*) *pallida*, C. B. Ad., Hald., De Kay. San Francisco, *Rowell*; San Antonio Arroya, teste Lea.

79. *Limnæa* (*Limnophysa*) *bulimoides*, Lea, Hald., De Kay. Fort Vancouver. San Francisco, *Rowell*. Also Eastern States. (Check-List.)

80. *Limnæa* (*Limnophysa*) *solida*, Lea, Hald., De Kay,+*L. apicina*, Lea, Küst. Oregon. Also Eastern States. (Check-List.)

81. *Limnæa* (*Limnophysa*) *ferruginea*, Hald., De Kay. Oregon.

82. *Pompholyx effusa*, Lea, Add. Pitt River, *Newberry*; Sacramento River, teste Lea.

83. *Physa* (*Physa*) *Lordi*, Baird. British Columbia, *Lord*; east of Fort Colville, W. T., *Am. N. P. B. Surv.*

84. *Physa* (*Physa*) *gyrina*, Say, De Kay, Küst., C. B. Ad., Hald.,=*Ph. elliptica*, Lea, De Kay,+*Ph. cylindrica*, De Kay,+*Ph. Hildrethiana*, Lea. Washington Territory, *Captain Simpson*; San Francisco, *Rowell*.

85. *Physa* (*Physa*) *ampullacea*, Gld.,=*Ph. bullata*, Gld. (non Pot. & Mich.). Oregon, *Cooper*; Lakes Rhett and Upper Klamath, *Newberry*.

86. *Physa* (*Physa*) *Gabbii*, Tryon. Sta. Aña Riv., Angelos Co. Also Mountain Lake, California.

87. *Physa* (*Physa*) *heterostropha*, Say, Gould, C. B. Ad., Desh., Küst., De Kay, Mrs. Gray, Pot. & Mich., Eaton,+*Ph. fontana*, Hald.,+*Ph. cylindrica*, Newc.,+*Ph. aurea*, Lea, De Kay,+*Ph. plicata*, +*Ph. glabra*, De Kay, +*Ph. osculans*, Hald. (part),+*Ph. striata*,+*Ph. subarata*, Mke.,+*Ph. Charpentieri*, +*Ph. Phillipii*, Küst., + *Ph. elliptica*, + *Ph. inflata*, Lea,=*Bulla crassula*, Dillw.,=*B. fontinalis*, Chemn., Schröter,=*Cochlea neritoides*, List. NORTH AMERICA, *passim*:—Chiloncynck, *Kennerley*; Hell Gate River, *Newberry*; San Francisco and Washington Territory, *Cooper*; Los Angeles, teste Lea. Also from Texas to British America and Arctic regions, and from Atlantic to Pacific, teste Binn.

†88. *Physa* (*Physa*) *costata*, Newc. Clear Lake, Cal., *Veatch*.

89. *Physa* (*Physa*) *virginea*, Gld. San Francisco, *Rowell*.

90. *Physa* (*Physa*) *humerosa*, Gld. Rio Colorado, *Willamson*; San Diego, *P. R. R. E.*

91. *Physa* (*Physa*) *virgata*, Gld. San Diego, *Webb*; Los Angelos; Cal. Ac. N. S.

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several of which are perhaps but modifications of circumboreal species which have been already traced to Eastern Asia. Even the series in Mus. Cum. are far from being accurate or complete. The inflexible rules of the British Museum have not yet allowed a single specimen of Dr. Baird's species to be transmitted to America, even for comparison.

92. *Physa* (*Physa*) *triticea*, Lea, Binn. MSS.* California, *Cooper*.
†93. *Physa* (*Physa*) *concolor*, Hald. Oregon.
94. *Bulinus* ‡ (*Bulinus*) *aurantius*, Cpr. [=*Aplexa*, auct.: *v.* Maz. Cat. p. 179],=*Ph. Peruviana*, Mke. [non D'Orb.]. Mazatlan, *Reigen*.
95. *Bulinus* (*Bulinus*) *elatus*, Gld. Mazatlan, *Reigen*.
96. *Bulinus* (*Bulinus*) *hypnorum*, Linn., Hald., C. B. Ad., Chen. et auct.,=*Ph. elongata*, Say, Gld., De Kay,=*Ph. elongatina*, Lewis. Northern Europe, Asia, America. Puget Sound, *Cooper*; common at junction of Yukron and Porcupine Rivers, Russ. Amer., *Kennicott*. Through Brit. and Russ. America, and from Kansas to Washington, D. C.; teste Binn.

Subfam. *Planorbinæ*.

97. *Planorbis* (*Planorbis*) *subcrenatus* §, Cpr. Oregon, *Nuttall*. [?Puget Sound, *Kennerley*.]
98. *Planorbis* (*Planorbis*) *tumens*, Cpr.,=*P. tenagophila*, Mke. (non D'Orb.),=*P. affinis*, Cpr. [Cat. Prov., non C. B. Ad.] Mazatlan, *Melchers*, *Reigen*. San Francisco, *Cooper*; Petaluma, teste Gld.
99. *Planorbis* (*Planorbis*) *vermicularis*, Gld.
100. *Planorbis* (*Helisoma*) *ammon*, Gld., =*P. Traskei*, Lea. Klamath Lake, Or. and Rhett Lake, Cal., *Newberry*. Ocogo Creek, Cal., *Williamson*; Kern Lake, Cal., *Cooper*; Monterey Co., *Trask*; Lagoons, Sacramento Valley, teste Lea.
101. *Planorbis* (*Helisoma*) *corpulentus*, Say, Hald., De Kay, Gld., Chenu, =*P. trivolvis* (pars), C. B. Ad. Columbia River, abundant, *U. S. E. E.* Also Eastern States.
102. *Planorbis* (*Helisoma*) *trivolvis*, Say, De Kay, Gld., Hald., C. B. Ad., Küst., Pot. & Mich., Eaton=*Bulla fluviatilis*, Say,+*Pl. regularis*, Lea,+*Pl. megastoma* +*Physa planorbula*, De Kay,+*Pl. macrostomus*+*Pl. corpulentus*, Whiteaves, +*Pl. lentus*, Gld.,+*Pl. trivolvis*, var. *fallax*, Hald.,=*Cochleat rium-orbium*, Lister, Petiver. Puget Sd., *Campbell*; Wright's Lake, Cal., *Newberry*; Ft. Vancouver, *Cooper*; San Francisco, *Rowell*; S. Diego; Mus. Smiths.; Horn Lake, teste Lea. Probably extends over whole continent, teste Binn.
103. *Planorbis* (*Menetus*) *opercularis*, Gld.,=*P. planulatus*, Coop. S. Francisco, *U. S. Expl. Exp.*; Whidby's Is., Cal., *Cooper*.
104. *Carinifex* ‖ *Newberryi*, Lea. Klamath Lake and Canoe Creek, Cal., *Newberry*; Clear Lake, Cal., *Veatch*.

Subfam. *Ancylinæ*.

105. *Ancylus Newberryi*, Lea. Klamath Lake, *Newberry*.
†106. *Ancylus crassus*, Hald. "**W.**" [Check-List.]
107. *Ancylus caurinus*, Coop. California, *Cooper*.
108. *Ancylus patelloides*, Lea. S. Francisco, *Cooper*; Arroya, San Antonio, Cal., Mus. Smith.
†109. *Ancylus Kootaniensis*, Baird. Brit. Columbia, *Lord*.
110. *Ancylus fragilis*, Tryon. "**W.**" [Check-List.]
111. *Acroloxus Nuttalli*, Hald. [*Velletia N.*, Binn. in list, May 4th.] Oregon, *Nutt.*
112. *Gundlachia Californica*, Rowell.

* So in first printed list and in two MSS.; but in Check-List of Dec. 9, *Ph. Troostiana*, Lea, is assigned to the West, instead of this species. The MSS. are probably correct.

‡ Non *Bulinus*, Sby., *olim*,=*Bulimus*, auct. However clearly *Bulinus*, Binn., may be right according to the antiquaries, it is far too like *Bulimus*, which has taken complete possession of the entire malacological world, to be allowed a resurrection in the same order. Surely burial for a given number of years ought to be allowed as evidence of death, especially if the infant-name scarcely even breathed the air of use, and its resurrection would breed malaria among terms thriving in the vigorous manhood of universal acceptance.

§ It is quite possible that this may prove a very finely grown specimen of *P. lentus*. Dr. Kennerley's shells are intermediate.

‖ Thus in Check-List, Dec. 9th. In that of May 4th, it appears as *Planorbis N.*; in the MS. list as *Carinifera*.

Suborder THALASSOPHILA.

Fam. *Siphonariadæ.*

†113. *Siphonaria lecanium*, Phil.: [Var. = *S. maura*, Sby. Var. *palmata*, Cpr., is possibly distinct. Mazatlan, *E. B. Philippi, Reigen*; Acapulco, *Jewett*; Cape St. Lucas, *Xantus.*]

†114. *Siphonaria æquilirata*, Cpr., [= *S. æquilorata*, Rve. Mazatlan, *Reigen*; C. S. Lucas, *Xantus*; Margarita Bay, very fine, teste *Pease.*]

†115. [*Siphonaria thersites*, Cpr. Neeah Bay, *Swan.*]

Doubtful, spurious, and extralimital species:—

Helix aspersa, Müll. "Sta. Barbara," *Kellett* and *Wood.* [Imported.]
Helix arbustorum, Linn.
Helix Sagraiana, D'Orb. [Certainly Cuban.]
Helix "*Sandiegoënsis*, Lea." Gld., P. R. R., vol. v. p. 331. "No such sp. described," teste Binney.
Helix peregrina, Bosc.
Bulimus Humboldti, Rve. ?"Mazatlan."
Bulimus Laurentii, Sby. "Sitka:" probably Sitcha in San Salvador, teste *Binney.*
Melania [*Bulimus*] *striata*, Perry. [*Vide anteà*, p. 520.]
Succinea aperta, Lea, = *S. rotundata*, Gld. Sandwich Is., *U. S. Expl. Exp.*
†*Physa Maugeriæ*, Gray, teste Woodward, Manual, p. 171; but probably equatorial S. America.
†*Siphonaria amara*, [Nutt. Admitted into the list by Mr. Binney, on the authority of Rve., as of Nutt.; but it lives on the Sandwich Is.; teste *Pease, Newcomb, U. S. E. E.*].

116. The Smithsonian Institution has lately issued a "Descriptive Catalogue of the species of *Amnicola, Viviparа, Bithynia, Valvata*, and *Ampullaria*," by Mr. W. G. Binney. It is abundantly illustrated with outline-woodcuts, and contains the synonymy corrected from all the accessible types. Dr. Stimpson is at present engaged in dissecting the molluscs; but none of his investigations have yet been published. The following is a *résumé* of the West Coast species, from a proof kindly furnished by the author.

Page. Fig.
4. *Amnicola longinqua*, Gld., Bost. Proc. v. 130. Colorado Desert. *Blake.*
5. 6. *Amnicola protea*, Gld., Bost. Proc. v. 129. Colorado Desert, *Blake, Webb.*
12. 45. *Vivipara*, Lam., = *Paludina*, Lam. [This genus, so fine and plentiful east of the Rocky Mountains, does not appear on the west.]
44. ,, *Paludina Nuttalliana*, Lea, Trans. Am. Phil. Soc. vi. p. 101, pl. 23. f. 109. [In text. In later manuscript list, this name appears as a synonym of] *Fluminicola* (Stimps., MS.) *Nuttallii*, Lea, = *Amnicola Nuttalliana*, Cp., Minn. Rep. p. 374, = *Leptoxis Nuttallii*, Hald., = *Anculosus Nuttallii*, Rve. ? + *Paludina seminalis*, Hds. (p. 46, f. 81). [? + *P. Hindsii*, Baird.] Columbia River, *Nuttall, Cooper*; Upper des Chutes Riv. and Klamath Lake, Or., *Newberry*; Roques R., Or.; Sacramento R., *Hinds*; Brit. Columbia, *Lord*; Canoe Creek and Pitt River, Cal., *Newberry.*
46. 80. *Bithinia nuclea*, Lea, = *Paludina n.*, Trans. Am. Phil. Soc. vi. p. 91, pl. 23. f. 103 [in text. In later MS. list, appears as synonym of] *Fluminicola virens*, Lea (*Paludina v.*, Lea; *Leptoxis v.*, Hald.), + *Paludina nuclea*, Lea. Wahlamat River, Oregon, *Nuttall* [Willamette, MS. list].

The following are added by Mr. Binney in his later MS. list:—

Valvata virens, Tryon. Clear Lake, Calif. [The Smithsonian duplicates have been unfortunately distributed under the name "*V. sincera*, Say," which had been previously given to the specimens, and under which they are quoted in the Check-List of 1860, no. 456. According to Mr. B., *V. sincera* is "like

ecarinate forms of *V. tricarinata*, Say," to which the Clear Lake specimens bear but slight resemblance.]

Pomatiopsis Binneyi, Tryon.

Fluminicola fusca, Hald. (*Leptoxis f.*). Shores of Lake Utah, *Capt. Burton.*

117. Of the West Coast species of Melaniadæ we are unable to offer any list embracing the synonymy, as the materials are at present in the hands of Mr. Tryon for elimination, and his labours are not yet sufficiently advanced to furnish a report. His Manual of the North American Melaniadæ will be published by the Smithsonian Institution. The animals of many species have already been dissected by Dr. Stimpson*. It is unfortunate that in the two most important branches of North American freshwater molluscs, the Melaniadæ and the Unionidæ, there exists a radical difference of opinion between the leading writers, which has sometimes assumed the appearance of personal animosity. Malacologists east of the Atlantic, unwilling to become partisans when the leading nomenclators of the rival schools are equally honoured, have to a great extent declined to pay attention to the unexhausted riches of the American waters, regarding any settlement of the disputed points as hopeless. Dr. Isaac Lea, who has spared no expense in illustrating his publications of the results of a life-long study, follows the restrictions on the priority-rule allowed by the British Association Committee. Other writers, however, claim a certainty in identifying the supposed species of Rafinesque and other similarly inaccurate authors, which would be considered by most English naturalists as not warranted by the few loose words of description given. It would be well if the student were permitted to start from the first carefully ascertained landmark, rather than from the defaced tracks of the first hunter.

In the Check-List of North-American Fluviatile Gasteropods, published by the Smithsonian Institution, June 1860, which contains the names of 405 (supposed) species of *Melania*, *Lithasia*, *Gyrotoma*, *Leptoxis*, and *Io*, Mr. Binney assigns the following eleven to the West Coast. None of them are accredited to the eastern division.

43. *Melania bulbosa*, Gld.
104. *Melania exigua*, Conr.
166. *Melania Menkeana*, Lea.
174. *Melania Newberryi*, Lea.
177. *Melania nigrina*, Lea. Clear Creek, Shasta Co.
211. *Melania plicifera*, Lea.
242. *Melania Shastaënsis*, Lea. Shasta and Scott Rivers.
243. *Melania silicula*, Gld. [= *M. plicifera*, small var., teste *Lea.*]
296. *Melania Wahlamatensis*, Lea.
297. *Melania Warderiana*, Lea.
360. *Melania fusca*, Hald.

118. Dr. Lea's Check-List of the Unionidæ (June 1860), after eliminating synonyms, assigns to America, north of Mexico, no fewer than 552 species of *Unio*, *Margaritana*, and *Anodonta*. The type-specimens of the species described by Dr. Gould from the United States Exploring Expedition were submitted to Dr. Lea's inspection, and confirmed his previous opinion that they were varieties of those before known. The *U. famelicus*, Gld., he pronounced to be a South-American shell; but it appears, without note, in the Check List, no. 133, probably by oversight. The only widely diffused species is the long-famed "pearl-mussel" of the Conway and other British streams. The following seven are accredited to the Pacific coast:—

* See his very interesting and important paper "On the structural Characters of the so-called Melanians of North America," in the 'American Journal of Science,' vol. xxxviii., July 1864, pp. 41–53. It appears that the sexual system is quite distinct from that of the ordinary Ctenobranchiate Gasteropods, and approaches the Cyclobranchiates.

281. *Unio Oregonensis*, Lea. [Comp. 534.]
484. *Margaritana margaritifera*, Lea. [Linn.]
494. *Anodonta angulata*, Lea.
499. *Anodonta Californiensis*, Lea.
531. *Anodonta Nuttalliana*, Lea.
534. *Anodonta Oregonensis*, Lea.
551. *Anodonta Wahlamatensis*, Lea.

Besides these, 36 species of *Unio* and *Anodonta* are assigned to Mexico and Central America in a separate list; but no distinction is indicated between the Pacific and the Atlantic slope of the mountain-range.

119. At the request of the Smithsonian Institution, Mr. Temple Prime, of New York, well known for his special devotion to this department, has consented to prepare a Manual of the Cyrenidæ inhabiting American waters. All the accessible materials from the West Coast are in his hands for examination. The first part of his "Monograph of the Species of *Sphærium* of North and South America" is printed in the 'Proc. Ac. N. Sc. Phil.' 1861, pp. 402 *et seq.*, and contains quotations of five species, nos. 4, 7, 9, 10, 11, with synonymy, from Washington Ter., Oregon, and California. He has kindly (in advance of his intended publications) furnished to Mr. W. G. Binney the following MS. "Synopsis of the Corbiculidæ of the West Coast of North America," with liberty to publish in this Report. It is here condensed, with synonyms and references, in the nomenclature of the writer.

Mr. Prime's List of West North-American Corbiculidæ* [Cyrenidæ].

1. *Corbicula convexa*, Desh., P. Z. S. 1854, p. 342, = *C. ventricosa*, Pr. MS. Mazatlan.
2. *Cyrena radiata*, Hanl., P. Z. S. 1844, p. 159. Realejo.
3. *Cyrena solida*, Phil., Abbild. 1846, p. 78, pl. 15. f. 9. Nicaragua; Belize.
4. *Cyrena triangula*, V. de Busch, P. Z. S. 1849, p. 78, pl. 2. f. 3, = *C. altilis*, Gld., Bost. Pr. 1852, p. 400, pl. 16. f. 5 *bis*, = *C. Mexicana*, pars, Maz. Cat., no. 165 (= *C. varians*, cat. prov.). Mazatlan.
5. *Cyrena insignis*, Desh., P. Z. S. 1854, p. 20; Il. Conch. 1861, p. 39, pl. 2. f. 2. California.
6. *Cyrena olivacea*, Cpr., Maz. Cat., no. 164, = *C. Fontainei*, Desh., MS. (non D'Orb., B. M. Cat. no. 253). Mazatlan.
7. *Cyrena acuta*, Pr., Ill. Conch. 1862, p. 387, pl. 14. f. 1. Centr. America.
8. *Cyrena Mexicana*, Sby., Zool. Il. 1829, p. 364 [Maz. Cat., no. 165 =] *C. varians*, cat. prov. pars, + *C. fragilis*, Desh. MS. + *C. æquilateralis*, Desh., P. Z. S. 1854, p. 20. Mazatlan.
9. *Cyrena Californica*, Pr., Proc. A. N. S. Phil. 1860, p. 276, = *C. subquadrata*, Desh., P. Z. S. 1854, p. 21 (nom. preoc.). California.
10. *Cyrena Panamensis*, Pr., Proc. A. N. S. Phil. 1860, p. 283, = *C. inflata*, Desh., P. Z. S. 1854, p. 23 (nom. preoc.). Panama.
11. *Cyrena Recluzii*, Pr., = *C. cordiformis*, Recl., Il. Conch. 1853, p. 251, pl. 7. f. 9 (nom. preoc.). Centr. America.
12. *Cyrena Cumingii*, Desh., P. Z. S. 1854, p. 22. Centr. America.
13. *Cyrena tumida*, Pr., = *C. angulata*, Desh., P. Z. S. 1854, p. 22 (nom. preoc.). Centr. America.
14. *Cyrena pullastra*, Mörch, Mal. Bl. 1860, p. 194. Realejo.
15. *Cyrena maritima*, C. B. Ad., Pan. Sh., no. 451. Panama.
16. *Cyrena sordida*, Hanl., P. Z. S. 1844, p. 159. Central America.
17. *Sphærium triangulare*, Say (*Cyclas t.*), New Harm. Dissem. 1829, p. 356. Mexico.
18. *Sphærium striatinum*, Lam. (*Cyclas s.*), An. s. Vert. vol. v. p. 560, 1818, = *C. edentula*, Say, *loc. cit.* p. 2, = *C. cornea* (Lam.), C. B. Ad., Cat., 1847, = *C. albula*, Pr., Bost. Proc. 1851, p. 155, + *C. tenuistriata*, Pr., p. 156, + *C. acuminata*, Pr., p. 158, + *C. inornata*, Pr., + *C. simplex*, Pr., + *C. modesta*, Pr., p. 159. *Hab.* N. York to Alabama, Connecticut to Illinois; Hell-gate River, W. T.
19. *Sphærium dentatum*, Hald. (*Cyclas d.*), Proc. A. N. S. Phil. 1841, p. 100. Oregon.

* The name *Corbicula*, having been first given to a species, and being itself a diminutive, is scarcely fitted to displace long-used generic appellations in marking the family-group.

20. *Sphærium occidentale*, Pr., Proc. A. N. S. Phil. 1860, p. 295, = *C. ovalis*, Pr., Bost. Proc. 1852, p. 276 (nom. preoc.), = '*Sph. ovale*, Stn.,' Add. Gen. vol. ii. p. 450. *Hab.* New York to Georgia; Vermont to Wisconsin; Hell-gate River, W. T.
21. *Sphærium nobile*, Gld. (*Cyclas n.*), Bost. Proc. 1855, p. 229 [Otia, p. 218]. San Pedro, *Webb.*
22. *Sphærium patella*, Gld. (*Cyclas p.*), Bost. Proc. 1850, p. 292 [Otia, p. 86; E. E. Moll. f. 527, type not returned to S. I.] Oregon.
23. *Sphærium Spokani*, Baird [P. Z. S. 1863, p. 69, f. 12, 13: *anteà*, p. 605]. B. Col.
24. *Sphærium tumidum*, Baird [P. Z. S. 1863, p. 69, f. 11: *anteà*, p. 605]. B. Col.
25. *Sphærium meridionale*, Pr., Proc. Ac. N. S. Phil. 1861, p. 414. Panama; Mus. Prime.
26. *Sphærium lenticula*, Gld. (*Lucina* * *l.*), Bost. Proc. 1850, p. 256. California.
27. *Sphærium subtransversum*, Pr., P. Z. S. 1860, p. 322. Mexico.
28. *Pisidium abditum*, Hald. [?ubi] = *Cyclas minor*, C. B. Ad. Bost. Proc. 1841, p. 48, = *P. obscurum*, Pr., Bost. Proc. 1851, p. 161, + *P. Kurtzii*, Pr., p. 162, + *P. zonatum*, Pr., p. 162, + *P. regulare*, Pr., Bost. Il. vi. 363, pl. 12. f. 11–13, 1852, + *P. notatum*, Pr., Bost. Il. vi. 365, pl. 12. f. 20–22, 1852, + *P. amplum* + *P. resartum*, Ingalls, MS., + *P. rubrum* + *P. plenum*, Lewis, MS., + *P. retusum*, Pr., P. Z. S. 1859, p. 322.
29. *Pisidium occidentale*, Newc. [Proc. Cal. Ac. Nat. Sc. 1861, p. 94]. San Francisco, *Rowell.*

120. Of the tertiary fossils throwing light on existing species no additional information has yet been published. We cannot but hope that the researches of Mr. Gabb, on the fossils collected by the Californian Geological Survey, will develope relations of great interest between the existing and former conditions of the continent. The Astorian fossils described by Mr. Conrad from the U. S. Exploring Expedition (vol. x., Geology, Philadelphia, 1849), and tabulated in the first Report, p. 367, belong to the Smithsonian Institution, but were not discovered there in 1860. All of them, however (including the indeterminate species), are figured in the atlas of plates. They resemble the fossils of the Pacific Railroad Expeditions in being very imperfect, for which reason the following criticisms may prove erroneous. The general aspect of the collection betokens the Miocene period.

Mya abrupta, Conr., may be the young of *Glycimeris generosa*, Gld.
Thracia trapezoides, Conr., may be *curta*, Conr.
Solemya ventricosa, Conr., has the aspect of a large *Lazaria.*
Tellina arctata, Conr., closely resembles *Macoma*, var. *expansa.*
Tellina emacerata, Conr., is perhaps *Bodegensis*, Hds.
Lucina acutilineata, Conr., appears to be *borealis*, Linn.
Cardita subtenta, Conr., = *Venericardia borealis*, Conr.
Nucula divaricata, Conr., = *Acila castrensis*, Hds.
Pectunculus patulus, Conr., may be *septentrionalis*, Midd.
Pectunculus nitens, Conr., resembles *Psephis tantilla*, Gld.
Pecten propatulus, Conr. A very fine specimen, enclosed in a large nodule from Oregon, was presented to the Brit. Mus. by Mr. C. Pace. If not identical with *Amusium caurinum*, Gld., it is most closely allied, especially to the Japanese form.

* Mr. Prime assigns no reason for changing Dr. Gould's *Lucina* into a *Cyclas*, nor any authority for "California." He was, perhaps, misled by the artist's engraved references to the figures 528, *a*, *b*, where he has drawn a rule, referring to the Cyclades above, instead of writing *Lucina*. It is assigned to "?Coast of Patagonia" in 'Otia,' p. 63, and to "?R. Janeiro" in 'E. E. Moll.,' p. 414. In each place the shell is compared to an *Astarte* or *Cyprina*, with lateral teeth. The type was not returned to the Smithsonian Institution; but the diagnosis states that it is "chalky, thickened within the deep and jagged pallial line, sculpture faint but decussated, and margin finely crenulated,"—characters more consistent with *Lucina*, s. g. *Myrtæa*, than with *Cyclas*. If the type cannot be recovered, perhaps the species may be dropped, as it is not the *Lucina* (*Myrtæa*) *lenticula*, Rve.

Terebratula nitens, Conr., is very probably *Waldheimia pulvinata*, Gld.
Bulla petrosa, Conr., has the shape of *Tornatina eximia*, Bd.
Crepidula prorupta, Conr., is certainly *princeps*, Midd.
Turritella, sp. ind., resembles *Mesalia lacteola*.
?*Dolium petrosum*, Conr., resembles the young of *Priene nodosa*, Chemn.
Fusus geniculus, Conr. A similar shell has just been taken at the Farallones by Dr. Cooper.

121. To correct the general table of "Mollusca of the West Coast of N. America" (First Report, pp. 298–345), and the deductions founded upon it (pp. 346-367), would involve the necessity of reprinting a considerable portion. The student, being now in possession of all the known sources of fresh information, can with his own pen strike out the spurious species, alter the synonyms, insert the newly discovered forms, and make the requisite corrections in the classified results.

122. With regard to the tropical fauna, the researches at Cape St. Lucas and in the interior of the Gulf of California, though leaving much to be desired, bear-out the general conclusions arrived-at in paragraphs 78-87. The evidence for the identity of specific forms on the Atlantic and Pacific sides of Central America has been greatly confirmed. Dr. Gould writes, "The doctrine of local limitations meets with so few apparent exceptions that we admit it as an axiom in zoology that species strongly resembling each other, derived from widely diverse localities, especially if a continent intervenes, and if no known or plausible means of communication can be assigned, should be assumed as different until their identity can be proved (*vide* E. E. Moll. Intr. p. xi). Much study of living specimens must be made before the apparent exceptions can be brought under the rule." It has, however, to be borne in mind that the researches of modern geology clearly point to considerable alterations in the existing configuration of continents, and in the consequent direction of ocean-currents, during the ascertained period of many species now living. Nor are we warranted in the belief that the existing fauna in any locality has been created at any one time, or has radiated from any single spot. To study the relations of living shells simply in connexion with the existing map of the world must lead but to partial results. The facts accumulating with regard to the British species, by tracing them through the northern drift (now found even on the Snowdonian range), to the oldest crag deposits when Europe was contained in far different boundaries, show how altered may have been the configuration of the new world when the oldest of its molluscs were first created. Coordinately with the glacial period, Central America may have been a group of islands; coordinately with the creation of *Saxicava pholadis* and *Chrysodomus antiquus*, the gulf-weed may have floated between the Rocky Mountains in the archipelago of West America, and Japanese molluscs may have known how to migrate to the Mediterranean shores. Dr. Gould's position may therefore be accepted in theory; yet, in practice, the "imperfection of the geological record"*, and even of our knowledge of existing species and their variations, demands that the greatest caution be exercised in building results on deductions from our ignorance. Already the fossil *Malea ringens* of the Atlantic has proved a "Rosetta Stone" to interpret the *Cypræa exanthema*, *Purpura patula*, and other Caribbean shells of the Pacific; and as the geology of the West Coast advances, so may we expect to find traces of previous denizens of

* No student of geographical distribution should omit to weigh carefully the chapter on this subject in Darwin's 'Origin of Species,' and the information given in Lyell's 'Antiquity of Man.'

American waters, which have bequeathed some species now flourishing, and others dying-out, to the existing seas. The present faunas of West America are perhaps the most isolated on the surface of the globe; yet, if we knew the ancestry of each specific form, we might find some first appearing with man on this planet, others first living even in historic times, others tracing their descent from remote periods, and it may be very distant localities, in the ages of the Miocene, possibly even of the Eocene oceans. These suppositions are not set forth as theories, but simply to guard against interpretations of facts based on conclusions which may be only the results of our necessarily imperfect information.

123. With regard to forms offering local peculiarities sufficient to distinguish them from correlative forms offering equal peculiarities in some other fauna, we are by no means warranted in assuming that these have sprung from different creations. If a race of men, migrating to a new continent, in a very few generations, or even in the next, develope an essentially different *physique*, it is fair to conclude that molluscs, borne by a change of currents to a distant region, or steadily migrating to the extreme limit of their conditions of life, will also change their appearance. If the publication of the "Darwinian Theory" has had no other effect, it has at least checked the propensity to announce "new species" for differences which may fairly be regarded as varietal. It must also be borne in mind, that if the views of Mr. Darwin be only a theory, such also is the name required for the prevalent opinion of separate creations for all diverse forms. What indeed can we possibly know of the mode of original creation of a single species? We can only prove that one or the other supposition best explains a certain class of facts. It is not necessary for a working naturalist to commit himself to an exclusive belief in either of these theories. He may perhaps best explain some facts by the doctrine of separate creation, others by that of natural selection. In either case it is his duty to trace-out, as far as possible, the limits as well as the powers of variation in every living form, and to guard against seeing that only which accords with his prevailing belief.

124. The study of European shells, as they exist in Norway, in Britain, in the Mediterranean, at the Canaries, or as they appear at different depths and stations in our own seas, still more as they occur in the widely separated periods of the later and middle tertiary ages, is an excellent preparation for the examination of either recent or fossil faunas in districts where our knowledge is fragmentary and unconfirmed. It may be safely stated that there are, in the American waters, many tropical forms from the West Indies and the Pacific shores, some temperate forms from California and the Atlantic, and many sub-boreal species in the Vancouver district and the European seas, not differing from each other more or even so much as forms universally allowed by malacologists to have had a common origin from Britain and the Mediterranean, from the Red and the Coralline Crag.

125. It is interesting to observe that, notwithstanding the probable connexion of the oceans through the Rocky Mountains during the Miocene age, there is extremely little similarity between the special temperate faunas of East and West America. Not a single species has yet been proved identical, and the allied forms are but few in number. They appear as follows:—

Californian species.	*U. S. Atlantic species.*
Clidiophora punctata.	C. trilineata (? = nasuta).
Lyonsia Californica.	L. (hyalina =) Floridana.
Macoma inconspicua.	M. fusca.
Angulus modestus.	A. tener.
Raëta undulata.	R. canaliculata.

Californian species.	*U. S. Atlantic species.*
Liocardium substriatum.	L. Mortoni.
Lunatia Lewisii.	L. heros.
Nassa mendica.	N. trivittata.
Amycla (species).	Amycla (species).

126. When, however, we approach the region in which boreal and sub-boreal forms occur, many species are found in common, and between others there is but slight difference. Yet even here there are more British than New England species in the West-coast fauna. As might be expected, the British species are for the most part those which are also found fossil, and therefore have had time to diffuse themselves widely over the hemisphere. It is, however, remarkable that many Crag species have reached Eastern Asia and West America which are not found in Grand Manan and New England. It is also extraordinary that certain special generic forms of the Crag, as *Acila*, *Miodon*, *Verticordia*, and *Solariella*, reappear in the North Pacific*. When seeking for an explanation of so remarkable a connexion between faunas widely removed in space and time, the correlative fact must be borne in mind, that the northern drift†, so widely diffused over Europe and Eastern America, has not yet been traced in the western region. The following Table exhibits, not only the identical but the similar species belonging to the northern faunas of the Atlantic and Pacific. In the Asiatic column, K denotes that the species occurs in the Kamtschatka region, J in Japan. In the second column, V signifies the Vancouver district, C the Californian, and I the Sta. Barbara group of islands. The species marked F are also fossil. In the third column, C denotes the Coralline, R the Red, and M the Mammaliferous Crag. The fourth contains the species living in the British seas; the fifth, on the American side of the Atlantic, *Gr.* standing for Greenland.

East Asia.	West America.		Crag.	British.	E. America.
K	V	Rhynconella psittacea ..	(Pleistocene)	psittacea	psittacea
—	V C	Xylotrya pennatifera....	—	pennatifera	—
—	V	Xylotrya fimbriata......	—	fimbriata	—
—	V C	Zirphæa crispata	C R M	crispata	crispata
K	V C	Saxicava pholadis	C R M	pholadis	pholadis
J	V C	Glycimeris generosa	Faujasii, C R	—	—
—	V	Sphænia ovalis	'?Binghami' ‡	Binghami	—
J K	V	Mya truncata	C R M	truncata	truncata
J K, lata	V	Macoma inquinata	lata, R M	proxima	proxima,&c
K	V	Serripes Grœnlandicus ..	R M	—	Grœnland.
K	V I	Venericardia borealis....	—	—	borealis
—	V	Astarte (compacta)	compressa, R M	compressa	compressa
—	V	Miodon prolongatus	corbis, C R	—	—
—	I F	Lucina borealis	C R M	borealis	—
—	I	Cryptodon flexuosus	C	flexuosus	—
China	I	Verticordia 9-costata....	cardiiformis, C	—	—
—	V C	Kellia suborbicularis	C R	suborbicul.	—

* Whether there be any similar correspondence in the Polyzoa is not yet known, Mr. Busk not having had time to complete his examination.

† See, in this connexion, a very accurate Table of the species which travel round Cape Cod, with their distribution in existing seas and over different provinces of the various drift-formations in the Old and New World, by Sanderson Smith, in Ann. Lyc. Nat. Hist. N. York, vol. vii. 1860, p. 166.

‡ From the Coralline Crag. Looks more like *ovalis*.

East Asia.	West America.	Crag.	British.	E. America.
J	V C Lasea rubra	C	rubra	—
J K	V C Mytilus edulis	R M	edulis	edulis
—	V C Modiola modiolus	?C R M	modiolus	modiolus
—	V Modiolaria marmorata ..	C R	marmorata	marmorata
J K	V Modiolaria lævigata	—	nigra	lævigata
—	I Crenella decussata	—	decussata	glandula
J K	V Nucula tenuis..........	C R M	tenuis	tenuis
insignis, &c.	V C I F Acila castrensis	Cobboldiæ, RM	—	—
J K	V Yoldia lanceolata	R M	—	lanceolata
—	V Leda minuta	R M	caudata	minuta
—	I Limæa subauriculata....	C	subauricul.	—
—	V C Hinnites giganteus	Cortesyi, C	—	—
(Asia)	V Limnæa palustris	M	palustris	palustris
—	V C Cylichna attonsa	cylindracea, CR	attonsa	—
—	V Haminea hydatis	M	hydatis	—
—	V C Dentalium Indianorum..	entale, M	entale	striolatum
J K, cæca	V Lepeta cæcoides	—	(cæca, *Nor.*)	cæca, *Gr.*
—	V Margarita helicina......	—	helicina	helicina
—	V Margarita ?Vahlii	—	—	Vahlii, *Gr.*
—	V Mesalia lacteola........	—	—	lactea, *Gr.*
—	V Lacuna vincta	M	vincta	vincta
K (turricula)	V Bela fidicula	turricula, R	turricula	turricula
—	V Bela excurvata	Trevelliana, R	Trevelliana	—
—	V C Scalaria Indianorum	—	communis	—
K	V Velutina lævigata	M	lævigata	lævigata
K	V Natica clausa	R	(Norway)	clausa
—	V C I Eulima micans........	polita, C R	micans	—
—	V Cerithiopsis tubercularis	C	tubercularis	—
—	V I Triforis adversus	C	adversus	—
—	C I Erato columbella	Maugeriæ, C R	—	(W. I.)
—	V C Purpura saxicola	—	lapillus	lapillus
—	V Chrysodomus liratus.....	—	—	10-costatus
—	V Trophon multicostatus ..	—	(Norway)	Gunneri

127. The following species (besides others dredged by Mr. A. Adams, but not yet determined) have been found on both the Asiatic and American shores of the N. Pacific, in addition to those recorded by Middendorff, *v.* Brit. Assoc. Report, p. 223.

Terebratella Coreanica.
Waldheimia Californica.
Waldheimia pulvinata.
Waldheimia Grayi.
Glycimeris generosa.
Schizothærus Nuttallii.
Solen sicarius.
Sanguinolaria Nuttallii.
Tellina Bodegensis.
Cardium modestum.
Amusium caurinum.
Placunanomia macroschisma.
Crepidula grandis.
Drillia inermis.
Lunatia pallida.
Priene Oregonensis.
Cerostoma foliatum.
Siphonalia Kellettii.

128. The Vancouver and Californian districts have so many characteristic species in common (111 out of 492), that they must be regarded as constituting one fauna, differing as do the British and Mediterranean regions. Full particulars as to the range of the different species may be expected in Dr. Cooper's Report to the Californian Geological Survey. One fact must, however, be here specially noted, viz. the great peculiarity of the island-fauna. Although the Sta. Barbara group are so near the mainland, the dredge has not only produced many species not known on the continent, but also many

before considered as essentially tropical. Along with these are not only some species of types hitherto regarded as almost exclusively Asiatic, as *Verticordia*, *Solariella*, and *Fulvia modesta*, but also some which belong to the sub-boreal district, as *Lucina borealis*, *Venericardia borealis*, and *Crenella decussata*. The latter belongs to the British, and not to the N. England form.

129. Of the blending of the temperate and tropical faunas on the peninsula of L. California we are still in ignorance. All we know is, that at Margarita Bay the shells are still tropical, and that at Cerros Island they are strangely intermixed. There is peculiar evidence of connexion between the faunas of the peninsula and of S. America, not only in the land-shells (*v. anteà*, p. 630), but in some of the marine forms. Beside identical species with wide range, as many Calyptræids, the following are coordinate between the North and South Pacific:—

Upper and Lower California.	*South America.*
Netastoma Darwinii.	N. Darwinii.
Solecurtus Californianus.	S. Dombeyi.
Semele rupium.	(Ditto, Galapagos.)
Callista *var.* puella.	C. pannosa.
Chama pellucida.	C. pellucida.
Liocardium substriatum.	L. Elenense.
Axinæa (Barbarensis.)	A. intermedia.
Verticordia novemcostata.	V. ornata.
Pecten æquisulcatus.	P. ventricosus.
Siphonaria thersites.	S. lateralis, &c.
Tonicia lineata.	T. lineolata.
Acmæa patina.	A. scutum, *D'Orb.*
Acmæa persona.	A. "Oregona," *H. C.*
Scurria mitra.	S. scurra.
Chlorostoma funebrale.	C. mœstum.
Mitra maura.	M. maura.
Ranella Californica.	R. ventricosa.
Priene Oregonensis.	P. cancellata.
Trophon multicostatus.	T. Magellanicus.

Time and space do not avail for pointing out further relations with exotic faunas; which indeed will be performed with greater correctness after Dr. Cooper shall have published his complete lists.

130. For the sake of avoiding the inconvenience of trinomial nomenclature, the subgeneric and varietal names have often been cited in this Report instead of the generic and specific, in order that the exact form of the shell quoted might be more quickly determined. The diagnoses of all the new species here tabulated are written for the press, and will shortly appear in the different scientific journals. Additional specimens will probably prove several forms to be conspecific which are here treated as distinct. In the present state of the science, absolute certainty is not to be attained. The object of the writer* has been principally to bring together the works of his predecessors, and so to arrange and describe the new materials that those who continue his labours may be able to draw their own conclusions from existing data. In order to facilitate reference, a brief index is here given of the subject-matter of the former and of the present Reports.

* The best thanks of the writer are due to Hugh Cuming, Esq., for the free use of his collection; to Messrs. H. & A. Adams, Hanley, Reeve, and Sowerby, for aid in identifying specimens; to the officers and naturalists connected with the Smithsonian Institution; to Dr. A. A. Gould, for very valuable corrections; and generally to authors and friends, who have kindly rendered him all the assistance in their power. He earnestly invites criticisms on the subject-matter of the two Reports; in order that they may be embodied, and errors corrected, in the Manuals of the West-Coast Mollusca which he has undertaken to prepare for the Smithsonian Institution.

Warrington, Aug. 22nd, 1864.

TABLE OF CONTENTS.

Report on Steam-Boiler Explosions.

By Professor AIRY, *F.R.S., Astronomer Royal.*

IN considering the cause of the extensive mischief done by the bursting of a high-pressure steam-boiler, it is evident that the small quantity of steam contained in the steam-chamber has very little to do with it. That steam may immediately produce the rupture; but as soon as the rupture is made and some steam escapes, and the pressure on the water is diminished, a portion of the water is immediately converted into steam at a slightly lower temperature and lower pressure; and this in the same way is followed by

other steam at a still lower temperature and pressure; and so on, till the temperature is reduced to 212° F., and the pressure to 0. Then there remains in the boiler a portion of water at the boiling-point, the other portion having gone off in the shape of steam of continually diminishing pressure. From this it is evident that the destructive energy of the steam, when a certain pressure is shown by the steam-gauge, is proportional to the quantity of water in the boiler.

I have long desired to possess myself of some theory and experiments which would enable me to form a numerical estimate of the proportion between the quantity of water at a given temperature and its destructive power. Several years ago I corresponded on this subject with my friend Professor W. H. Miller, of Cambridge; but it appeared difficult then to find sufficient materials for a certain conclusion. In the present year I again requested him to take up the subject; and I received from him a complete theory on the generation of steam in the way which I have described, with references to the latest trustworthy experiments bearing on the subject. I also received from him references to the experiments of the French General Didion, illustrating the power of gunpowder in cannons. About the same time, by the kindness of Messrs. Ransomes and Sims, of Ipswich, experiments had been made, at my request, by their able engineering superintendent, George A. Biddell, Esq., on the quantity of water which does actually escape in steam from a boiler in which the pressure has been raised to 60 lbs. per square inch. The result of this experiment agreed well with Professor Miller's theory, suggesting only a small correction, which Professor Miller refers, and, I doubt not, justly, to the iron of the boiler. From these I have been able to obtain a result which I believe to be worthy of every confidence.

I will first state, as the immediate result of Mr. Biddell's experiments, that when there were, in the boiler of a small locomotive, 22 cubic feet of water at the pressure of 60 lbs. per square inch, and the fire was raked out, and the steam was allowed gently to escape with perfect security against priming, the quantity of water which passed off before the pressure was reduced to 0 was $2\frac{3}{4}$ cubic feet, or one-eighth of the whole.

In regard to the use made of Professor Miller's theory, Professor Miller had succeeded in obtaining a numerical expression for the pressure of the steam at twelve different measures of the volume occupied by water and steam, which expression I have succeeded in integrating accurately; and I have thus obtained an accurate numerical expression for the destructive energy of the steam. In regard to the use of General Didion's experiments, these experiments give the velocity of the ball, in cannon of different sizes, produced by different charges of powder. I have found, by trial with the formula $\dfrac{Wv^2}{2g \times \text{weight of powder}}$, which of these experiments exhibits the greatest energy per kilogramme of powder, and have adopted it in the comparison.

The result is as follows:—

The destructive energy of one cubic foot of water, at 60 lbs. pressure per square inch, is equal to the destructive energy of two English pounds of gunpowder in General Didion's cannon-experiments.

General Didion's experiments were made, as I understand, with smooth-bored cannon. It cannot be doubted that much energy is lost in the windage, some also from the circumstance that the propelling power ceases at the muzzle of the gun before all the energy is expended, and some from the coolness of the metal. If we suppose that, from all causes, one-half of the energy was lost, then we have this simple result:—

The gauge-pressure being 60 lbs. per square inch, one cubic foot of water is as destructive as one pound of gunpowder.

In one of Mr. Biddell's experiments, the steam-valve was opened rather suddenly, and the steam escaped instantly with a report like that of a very heavy piece of ordnance. This is not to be wondered at; for it appears, from the comparison above, that the effect was the same as that of firing a cannon whose charge is 44 lbs. of powder.

Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 *Atmospheres. By* C. W. Siemens, *C.E., F.R.S.*

It has been repeatedly observed that the insulation-resistance of deep-sea cables improves on their being submerged, unless the cables be absolutely faulty. But it remained for a long time an open question whether this improvement was to be ascribed to the pressure of the water or only to the lower temperature at the bottom. This question has, however, been set at rest by the electrical tests applied to the Malta-Alexandria cable at the Gutta-percha Works, Mr. Reid's arrangements enabling me to subject the coils, during their electrical examination, to a pressure of 600 lbs. on the square inch.

Before pressure was put on, the coils were always immersed for 24 hours in water, at a constant temperature of 24° C. The electrical resistance of the insulating covering of each knot of the conductor was measured before, during, and after pressure, the temperature of the pressure-tank being always maintained at 24° C. The average improvement of the insulation under this pressure, after the zinc current had been kept to the cable during one minute, was found to be nearly 14 per cent., or assuming the improvement to be directly proportional to the pressure shown by the gauge, the resistance R_p of any coil of this cable under the pressure P, in lbs., per square inch, whose resistance at atmospheric pressure was R, would be expressed by

$$R_p = R\,(1+0{\cdot}00023P).$$

The observations of which the coefficient 0·00023 is a mean would be too voluminous to repeat here; the principal part of them is included in the weekly reports on the electrical conditions of the cable during its manufacture.

A pressure-tank has since been constructed at the Gutta-percha Works, in which a considerably greater pressure can be attained. I have taken advantage of this, to have the separate knots of the core of the Oran-Carthagena cable, now in course of manufacture, tested under a pressure of 300 atmospheres—fully equal to that to which the cable will be exposed at the bottom of the Mediterranean*.

The same opportunity has enabled me also to make a few experiments with a view to determine the dependence of the insulation-resistances of gutta percha, india-rubber, and of a combination of both these materials from external pressure. I have further extended the experiments to ascertain the ratio of increase of the insulation-resistances by polarization or electrification under different pressures.

The results are collected in the following Tables:—

* The depth of the Mediterranean in that part does not exceed 1500 fathoms.

TABLE I.—*Gutta-percha-covered Wire.*

Pressure in atmospheres. P.	Coil 13.				Coil 18.			
	R. 1 min.	$\frac{\Delta R}{151.\Delta P.}$	R. 3 min.	$\frac{\Delta R}{192.\Delta P.}$	R. 1 min.	$\frac{\Delta R}{145.\Delta P.}$	R. 3 min.	$\frac{\Delta R}{179.\Delta P.}$
	millions.		millions.		millions.		millions.	
0*	151		192		145		179	
		0·0034		0·0031		0·0033		0·0034
75	190		237		181		224	
		0·0047		0·0033		0·0034		0·0038
150	243		284		218		275	
		0·0028		0·0040		0·0029		0·0034
225	275		341		244		320	
		0·0036		0·0037		0·0036		0·0038
280	305		380		273		357	

Remarks.—* The cable had been put to earth for a considerable time before these measurements were made, and was put to earth for 15 min. after each 3 min. test.

TABLE II.—*Gutta-percha-covered Wire* (No. 22).

Pressure in atmospheres. P.	1 minute.		4 minutes.		9 minutes.		14 minutes.		19 minutes.	
	R.	$\frac{\Delta R}{237\Delta P.}$	R.	$\frac{\Delta R}{293\Delta P.}$	R.	$\frac{\Delta R}{331\Delta P.}$	R.	$\frac{\Delta R}{349\Delta P.}$	R.	$\frac{\Delta R}{354\Delta P.}$
	millions.		millions.		millions.		millions.		millions.	
0*	237		293		331		349		354	
		0·0026		0·0031		0·0032		0·0032		0·0037
75	283		362		411		434		452	
		0·0044		0·0051		0·0047		0·0047		0·0048
150	362		474		527		557		579	
		0·0042		0·0039		0·0053		0·0055		0·0065
225	436		559		659		701		752	
		0·0047		0·0065		0·0026		0·0034		0·0034
300	519		701		724		789		841	
		—		—		—		—		—
0†	252		324		359		371		376	
		—		—		—		—		—
0‡	242		305		346		366		366	

Remarks.—* Between each series of observations the cable was put to earth for two hours. † Immediately after pressure. ‡ Three hours after pressure.

TABLE III.—*Gutta-percha-covered Wire* (No. 22).

Time.	Pressure in atmospheres. P.	Resistance. R.	$\frac{\Delta R}{381\Delta P.}$	Remarks.
h m		millions.		
7 0	0	380		Current had been kept on the cable half-an-hour to complete the electrification previous to taking the first reading, and was not interrupted during the series.
			0·0038	
7 5	75	490		
			—	
7 9	0	402		
			0·0042	
7 20	150	642		
			—	
7 22	0	415		
			0·0044	
7 28	225	790		
			—	
7 31	0	429		
			0·0052	
7 39	300	1027		
			—	
7 42	0	429		
			—	
10 0	0	381		

TABLE IV.—*India-rubber-covered Wire.*

Time.	Pressure in atmospheres. P.	Resistance. R.	$\frac{\Delta R}{128 \Delta P}$.	Remarks.
h m		millions.		
10 0	0	128	−0·00083	Zinc-current had been half-an-hour to cable to complete electrification, and kept on during the observations uninterrupted.
10 10	75	120	−0·00042	
10 17	150	116	−0·00031	
10 28	225	113	−0·00125	
10 33	300	101		This reading was scarcely made, when the needle of the galvanometer showed a considerable fault to have occurred. The fault was afterwards found to be in the stuffing-box.

TABLE V.—*India-rubber-covered Wire.*

Pressure in atmospheres. P.	1 minute.		4 minutes.		9 minutes.		14 minutes.		19 minutes.	
	R.	$\frac{\Delta R}{89}$.	R.	$\frac{\Delta R}{87 \Delta P}$.	R.	$\frac{\Delta R}{95 \Delta P}$.	R.	$\frac{\Delta R}{105 \Delta P}$.	R.	$\frac{\Delta R}{105 \Delta P}$.
	millions.		millions.		millions.		millions.		millions.	
0*	89	−0·0016	87	−0·0015	95	−0·0020	105	−0·0028	105	−0·0027
75	78	−0·0009	77	−0·0008	81	−0·0007	83	−0·0008	84	−0·0013
150	72	−0·0008	72	−0·0012	76	−0·0021	77	−0·0017	74	−0·0014
225	67	−0·0003	64	+0·0002	61	+0·0004	64	−0·0003	63	0
300	65	—	65	—	64	—	62	—	63	—
0†	107	—	111	—	109	—	98	—	95	—
0‡	87		87		87		94		94	

Remarks.—* Cable to earth two hours between each series. † Immediately after pressure. ‡ Three hours after pressure.

TABLE VI.—*Wire covered with India-rubber and Gutta percha* (No. 13).

Time.	Pressure in atmospheres. P.	Resistance. R.	$\frac{\Delta R}{59 \Delta P}$.	Remarks.
h m		millions.		
11 0	0	59	0·0011	Zinc-current had been kept on the cable during an hour before the first reading was made, and not interrupted during the series.
11 9	75	64	0·0011	
11 17	150	69	0·0005	
11 29	225	71	0·0011	
11 36	300	76	—	
11 39	0	58		

TABLE VII.—*Wire covered with India-rubber and Gutta percha* (No. 27).

Time.	Pressure in atmospheres. P.	Resistance. R.	$\frac{\Delta R}{77\Delta P}$.	Remarks.
h m		millions.		
2 0	0	77		Current had been on 1½ hour.
			0·0021	
2 10	75	89		
			0·0019	
2 18	150	100		
			0·0019	
2 27	225	111		
			0·0028	
2 40	300	127		
2 47	0	80	—	Immediately after pressure.
2 55	0	75	—	Ten minutes after pressure.

Tables I., II., and III. contain the results of experiments with gutta-percha cables. The gutta-percha-covered conductor used consisted of coils of copper strand (three wires), weighing 72 lbs. per knot, and covered to 0·26 inch with three coatings of gutta percha, with intervening thin layers of Chatterton's compound. The length of each of the coils was about a knot, and two of them were always placed in the pressure-tank at the same time; but they were tested separately.

The coils, which had been for twenty-four hours previously maintained at a constant temperature, were placed in the pressure-tank, which was kept during the experiments at the same temperature. One end was sealed, and the other passed through a stuffing-box in the side of the tank to the testing-board.

When the coils were in the tank, a vacuum was first made, then the water admitted, and, finally, the pressure put on in stages of 75 atmospheres, until the pressure of 300 atmospheres was attained.

The battery-power used was uniformly 200 elements (Daniell's).

The resistances given in the Tables are reduced from the deflections of a Dubois' zinc galvanometer, and are expressed in millions of mercury (mètre) units.

Table I. contains the results of some measurements of electrical resistance of the coils, noted after the current had been active for one and three minutes respectively, at various pressures. The cable was put to earth for a sufficient time between the readings, under different pressures, to prevent the residuum, or electrification by the current, of one test interfering with the values obtained for the next test.

The columns headed $\frac{\Delta R}{R.\Delta P}$ in the Tables give the ratios of increase of resistance due to a unit of pressure. The other columns are self-explanatory.

The experiments recorded in Table II. were made to determine the effect of pressure on the capacity for electrification of gutta percha. It is well known that the apparent insulation of gutta percha increases during the first half-hour from the moment the battery is put to it, after which it becomes nearly constant. The observations in this instance were continued for 19 minutes after making contact with the battery.

The first series of readings were made under atmospheric pressure after 1, 4, 9, 14, and 19 minutes' continuance of current respectively. The cable was then put, for two hours, to earth. Similar series were made under various pressures up to 300 atmospheres, putting the cable between each series to

earth for the same length of time; also two such series without pressure, the first immediately after taking off the pressure, the other after the cable had been three hours to earth.

It appears from the coefficients in the columns headed $\frac{\Delta R}{R.\Delta P}$ in this Table, that pressure has no marked influence on the electrification of gutta percha; the relative amount of electrification being, in all cases, only a function of the time during which the current is kept on. The same constancy of electrical resistance or electrification was observed in regard to differences of temperature by Mr. Fleeming Jenkin as early as 1859 *.

In the measurements recorded in Table III., the electrification of the cable was completed under atmospheric pressure before taking the first reading. The pressure was then raised to 75 atmospheres, under which the resistance was observed. The pressure was then taken off, and the resistance observed again. Readings were then made alternately under atmospheric pressure and pressures increased each time by 75 atmospheres.

It will be observed that the resistance of the insulating covering increased on the application of the pressure of 75 atmospheres from 380 to 490 millions, and on taking off this pressure did not, as might have been expected, immediately fall back again to its original value, but only after an interval of three hours.

The coefficients in Tables I., II., and III. are on an average the same as those obtained with the core of the Malta-Alexandria cable.

I may further mention here that the tests were extended to measuring the induction of the insulating materials. The results proved *that the inductive capacity of gutta percha is not affected by pressure.*

Being desirous to ascertain whether the same physical laws indicated by these observations were equally applicable to other insulating materials, I subjected a length of wire covered with india-rubber to the same test. A length of half-a-mile of copper wire, No. 16, B.W.G., which had been covered with three coats of masticated india-rubber by the longitudinal process introduced by me some years ago, was kindly placed at my disposal by the Gutta-percha Company, after having been submerged in the canal at Wharf Road for a period of about 18 months. At the ends where the core had been exposed to the air and light, the india-rubber had turned into a viscid mass, but, on raising the coil out of the water, it was found to be perfectly sound, although the india-rubber had turned white by absorption of water, and was completely covered with vegetable and animal substances. Its electrical resistance, according to the tests of Dr. Esselbach and of Mr. Willoughby Smith, Electrician to the Company, was still very high.

Table IV. contains the resistances of the india-rubber coating, in millions of units, after the zinc-current had been kept half-an-hour on, under various pressures; and Table V. the resistances under different pressures read off after the current had been on 1, 4, 9, 14, and 19 minutes respectively.

From the test in the former of these Tables, the surprising fact was demonstrated *that the electrical resistance of india-rubber decreases as the pressure is increased*, being the reverse of the behaviour of gutta percha.

The vertical columns in Table V. corroborate this, whilst the horizontal columns (showing the resistance after the current had been active during the stated intervals of time under various pressures) indicate this further remarkable difference between the two insulating materials, that whereas, in the

* Report of the Twenty-ninth Meeting of the British Association at Aberdeen in 1859, Trans. of Sect. p. 248.

case of gutta percha, the increase of electrification is proportional to the increase of electrical resistance by pressure, the electrification of india-rubber decreases with the pressure in a ratio surpassing the decrease of electrical resistance.

Struck by this extraordinary difference in the effects of pressure upon these two materials, I next submitted to my tests a wire covered first with india-rubber by the longitudinal process, and thereupon with gutta percha to the thickness of 0·175 inch.

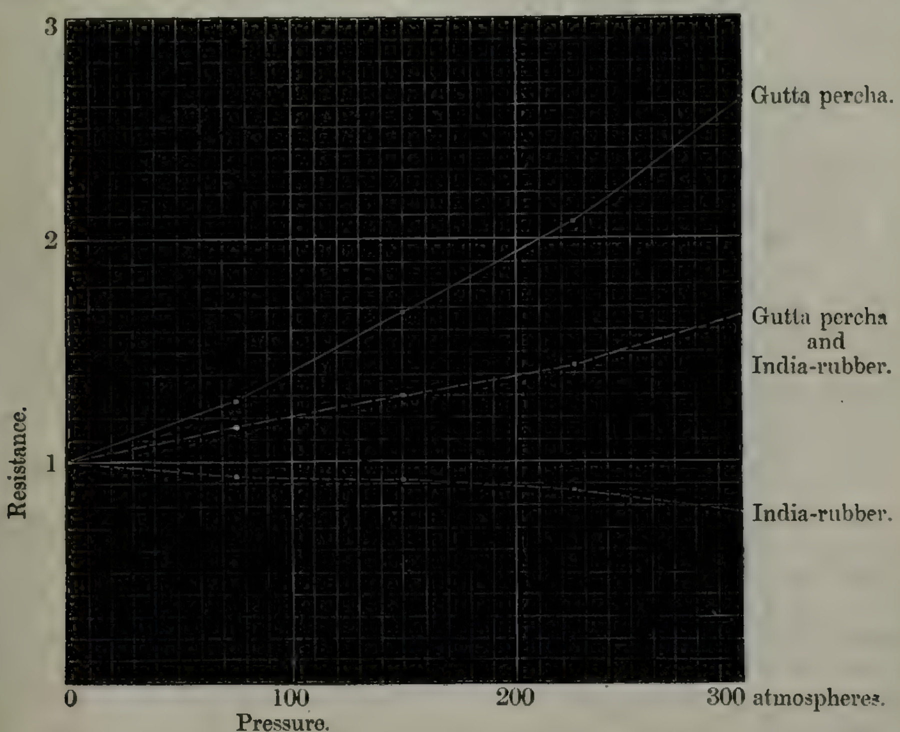
In submitting a wire so covered to pressure, I made certain that the results obtained could not be influenced by any direct action of the water upon the india-rubber by absorption or otherwise, owing to the intervention of the gutta percha.

Tables VI. and VII. contain the resistances of the insulating materials at different pressures, the electrification being completed.

These observations are interesting in so far as they confirm the foregoing results with gutta percha and india-rubber, the coefficients being a mean between those of the two materials separately, as will be seen by the following:—

Mean of coefficients for gutta percha from Tables I., II., and III. . . $+0·0041$.
The same for india-rubber from Tables IV. and V. . . . . $-0·0009$.
The same for both these materials combined from Tables VI. and VII. $+0·0016$.

The accompanying diagram, constructed from Tables III., IV., and VII., is added to give a graphic representation of the variations observed in the



electrical resistances under increasing pressures. The abscissæ represent pressures, and the ordinates the electrical resistances when the maximum of electrification was attained.

These results go to prove that external pressure exercises a decided influence upon the electrical condition of gutta percha and india-rubber, and probably upon every other substance in nature. They go to prove, moreover, that this change of electrical condition cannot be attributed to general physical laws,—as, for instance, to the supposition that the nearer approach of the particles under the influence of external pressure interferes with their transmission of electrical motion,—but must be referred to the specific atomic arrangement of the material in question.

It appears to me desirable that these researches should be extended to other materials, including both good and bad conductors, in order to arrive at more satisfactory general conclusions; but such experiments are of a difficult and expensive nature, and I thought that even the few results I have put together in this paper would be acceptable to the Association.

On the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees. By CHARLES M. PALMER.

THE art of constructing ships dates from remote antiquity, and we find in history, sacred and profane, many particulars of the ships in use in ancient times. As civilization advanced, and the science of navigation became better understood, ships increased in size, strength, capacity, and speed. Year after year brought its improvements, century after century its changes, until the art of shipbuilding in wood approached perfection, and the rude coracles and row galleys of our forefathers had given place to the clipper-ship, with its fine lines, tapering masts, and flowing canvas, the merchantman driven by steam at a high speed across the ocean, and the three-decked, steam-propelled man-of-war. Then a demand arose for vessels of a still higher character—merchantmen possessing still greater speed, men-of-war sufficiently powerful to resist the destructive shot and shell which the genius of men like our friend and townsman, the President of the Association, was inventing. With wood as the material to be employed, this demand could not be met; but human skill was equal to the emergency. The important discovery was made that "ships built of iron float lighter, strength for strength, than ships built of wood;" and although for many years the prejudices of some men and the interests of others prevented the general adoption of the principle, it eventually triumphed, and now iron is rapidly superseding wood as material of which ships are constructed.

The principal advantages that are claimed for ships of iron, as compared with vessels of timber, are briefly these:—

In vessels of 1000 tons the iron ship will weigh 35 per cent. less than the timber vessel, the displacement of water being the same. The iron ship will therefore carry more weight, and as the sides are only about one-half the thickness, there will consequently be more space for cargo. The additional strength obtainable, too, allows iron ships to be built much longer and with finer lines, thus ensuring higher sailing or steaming qualities, with greater carrying power, and therefore greater commercial results. In wooden vessels, repairs of ruinous extent are frequently required, while the repairs in iron ships are generally of a lighter character, and are only needed at long intervals. An iron ship is not liable to strain in a heavy sea, whereas the straining of a timber vessel often damages a valuable cargo. The bilges of an iron ship can be kept clean and free from the disease-engendering

bilge-water which is always found in a wooden ship. Moreover, the use of iron masts, steel yards, and wire rigging effects a very large saving of weight, and affords the greatest facilities for the application of patent reefing sails and other appliances by which economy of labour is attained, and many risks of loss of human life avoided.

As to the form of building iron ships, and the manner of combining the iron so as to obtain the requisite amount of strength with the least amount of material, much difference of opinion exists amongst practical men. The angle-iron frame and plating of the iron vessel take respectively the places of the timbers and planking of the wooden ship; and it has been found by experience that plating $\frac{1}{8}$th of an inch thick is equivalent in effect to planking of oak one inch thick, while plating $\frac{11}{16}$ths of an inch thick is equal to planking of oak 5 inches thick. As in the largest American wooden vessels the plank is seldom more than 5 inches thick, so it may be argued on the above data that the plating of the largest iron ship need not be more than $\frac{11}{16}$ths thick; and that any strength required above that which such plating would give, should be obtained by means of framework. Many practical men, however, advocate the system of light framework, and, in order to obtain the measure of strength necessary, the application of thicker plates. That the principle of strong framing and plating of moderate thickness is most advantageous, may be shown by many facts other than those which are derived from the most modern practice of wood shipbuilding. The strength of an iron ship, as in a girder, depends on its capability to resist the buckling and tensile strains that it is called on to bear; but I believe that we have in reality only to make a ship strong enough to resist the *buckling strain*; and I am led to this conclusion by experiments conducted for that celebrated work, the Britannia Bridge, which proved that in constructions of wrought iron the resistance to the tensile strain is much greater than the resistance to buckle, and, in consequence, the upper parts of the girders are made much stronger than the lower parts. We have, in my opinion, to make the parts of an iron ship, in principle, like a girder. A girder, however, is at rest and the strains are always in some known direction; but in a ship whose position is ever varying, it requires to be so constructed as to resist the strains in such varied positions. If the side of a ship could remain, as in a girder, constantly vertical, then the advocates for the thick plates and small frames might be able to show that their system was the most economical way to obtain the requisite strength; but as such side, if laid over, as it is in a ship at sea, would, without support, bend or buckle of its own weight, *it is evident that the framing is absolutely necessary* to keep the plating firm in position, and consequently the strength of the ship depends in a very great degree on the strength of the framing. Another fact that shows the economy of strong frames, is that a plate, with a piece of angle-iron attached to its edge, would bear much more before buckling than a similar plate increased in thickness so as to weigh the same as the plate and angle-iron. But the great and most important argument in favour of moderately thick plates and strong framing is, that all the work must be put together by hand; for though many attempts have been made to rivet ships by machinery, none seem yet to have been successful even in a mechanical point of view. So soon, therefore, as the thickness of plates and the size of the rivets pass the point at which the workman with *ordinary* exertion can accomplish good work, then the attachment of the parts by means of riveting is subject to the risks of imperfect workmanship. It is, therefore, my opinion, both in a practical and theoretical point of view, that we

ought not to use plating in any vessel, however large, more than about three-quarters of an inch thick.

In the early period of iron shipbuilding the frames were generally composed of simple bars of angle-iron, but they are now usually doubled by a reverse bar, which is riveted on the principal bar, so as to make a frame whose cross section is like the letter Z, and this form is perhaps as strong as any that could with economy be obtained. In some large ships, plates of iron on edge were placed between the angle-irons so as to enlarge the section. The frame thus formed required longitudinal supports to bind it together, and those all-important strengthening pieces, called stringers, box and other keelsons were introduced. The great advantage of these appliances is, that they may be placed exactly where the ship requires support, and that, too, with the least possible amount of iron. As to the application of these stringers and keelsons, the shipbuilder must be guided by the form, proportions, and other circumstances connected with the construction of the ship.

To show how far this system of longitudinal framing may be carried with success, I may point to the ship 'Richard Cobden,' designed by Mr. Guppy (known in connexion with the construction of the 'Great Britain') in 1844. This vessel was framed so as to leave rectangular spaces to be covered with the outside plating; these spaces were $2\frac{1}{2}$ feet vertically, and 5 and 6 feet horizontally, and in no part of this highly successful construction were the plates more than $\frac{5}{8}$ths thick.

As to the riveting, which is of the utmost importance in shipbuilding, I shall say a few words. In making boilers, single riveting is usually adopted, but there the strain is constantly in one direction. In ships the direction of the strain is changeable as the vessel moves; therefore double, and in some cases triple riveting has been used with great advantage. Mr. Fairbairn estimates that the tensile effect of single riveting is represented by 56, double riveting by 70, and triple riveting by 90, and these proportions would appear to hold good whether in chain or zigzag riveting. The former, however, has been shown by experiment to have an advantage over the latter of about 20 per cent. in the tensile strain.

In concluding this necessarily brief account of the general principle on which iron ships are constructed, I may mention that the only objections that can reasonably be urged against ships made of this material, are that the compasses are difficult of adjustment, and that the bottoms get foul. Let us, however, hope that science, in the promotion of which the British Association is so powerful an agent, may in a short time show us how both these difficulties may be overcome.

I now proceed to what is perhaps the more interesting division of this paper, viz., a sketch of the progress of iron shipbuilding on the Tyne, Wear, and Tees.

For a very long period the district of the Tyne, Wear, and Tees has been famous for its shipping. A committee of the House of Commons, that sat so far back as the year 1642, designated Newcastle as "the nursery for shipping," and Defoe, writing of the Tyne in 1727, states that "they build ships here to perfection—I mean as to strength and firmness, and to bear the sea."

The history of iron shipbuilding in this district does not commence, however, until the year 1840. In March of that year, the 'John Garrow,' of Liverpool, a vessel of 800 tons burthen, the first iron ship seen in these rivers, arrived at Shields, and caused considerable excitement. A shipbuilding firm at Walker commenced to use the new material almost immediately, and

on the 23rd of September, 1842, the iron steamer 'Prince Albert' glided from Walker slipway into the waters of the Tyne.

During the next eight or ten years very little progress was made. The vessels mostly in demand were colliers, and no one thought of applying iron in their construction; but about the year 1850, the carriage of coals by railway began seriously to affect the sale of north-country coal in the London market, and it became essential, in the interest of the coal-owners and others, to devise some means of conveying the staple produce of this district to London in an expeditious, regular, and at the same time economical manner. To accomplish this object, I caused an iron screw steamer to be designed in such a manner as to secure the greatest possible capacity, with engines only sufficiently powerful to ensure her making her voyages with regularity. This vessel, the 'John Bowes,' the first screw collier, was built to carry 650 tons, and to steam about nine miles an hour. To the success of this experiment may be attributed, in a great measure, the present important development of iron shipbuilding in this district, and the fact that we continue to supply so largely the London market with coals. On her first voyage, the 'John Bowes' was laden with 650 tons of coals in four hours; in forty-eight hours she arrived in London; in twenty-four hours she discharged her cargo; and in forty-eight hours more she was again in the Tyne; so that in five days she performed successfully an amount of work that would have taken two average-sized sailing colliers upwards of a month to accomplish.

The amount of prejudice with which nautical men, and persons engaged in the shipping and coal trades, opposed the introduction of screw colliers was great. They argued that it would be impossible for steamers carrying 650 tons of coals, and costing about £10,000, to compete with vessels that consumed no fuel, and which, though carrying only half the quantity, cost little more than £1000, or only one-tenth the amount. I was, however, confident of the result, and persisted in the development of the system. How far my views have proved correct will be borne out by the following Table, which shows the number of cargoes and tons of coals imported into London by screw steamers in each year, from July 31, 1852 (the date of entry of the first screw steamer, 'John Bowes') to June 30, 1863:—

Year.		Cargoes.		Tons.
1852	... ...	17	... making ...	9483
1853	... ...	123	... " ...	69,934
1854	... ...	345	... " ...	199,974
1855	... Crimean War ...	174	... " ...	85,584
1856	... ...	413	... " ...	238,597
1857	... ...	977	... " ...	547,099
1858	... ...	1127	... " ...	599,527
1859	... Italian War ...	899	... " ...	544,614
1860	... ...	1069	... " ...	672,476
1861	... ...	1299	... " ...	851,991
1862	... ...	1427	... " ...	929,825
1863	Half-year ending June ...	714	... " ...	463,609
				5,212,713

By this Table it is seen that a total quantity of 5,212,713 tons of coals have been imported into London by screw colliers, and, in addition to this, large and increasing quantities have been taken to other ports both in this country and abroad. Since its first introduction, too, the screw collier has been greatly improved, and the facilities for loading and discharging very largely augmented. The screw collier 'James Dixon' frequently receives 1200 tons of coals in four hours, makes her passage to London in thirty-two

hours, there (by means of the hydraulic machinery which our President invented, amongst the other inventions which distinguish his name) discharges her cargo in ten hours, returns in thirty-two hours, and thus completes her voyage in seventy-six hours. The 'James Dixon' made fifty-seven voyages to London in one year, and in that year delivered 62,842 tons of coals, and this with a crew of only twenty-one persons. To accomplish this work on the old system with sailing colliers would have required sixteen ships, and 144 hands to man them.

One of the great difficulties we had to encounter in perfecting these vessels was in the ballasting. To dispense with the necessity of shipping shingle or chalk as ballast, many costly experiments were tried, and at length, by a system of double bottoms, the construction of which adds to the strength of the ships, the ballasting of the vessels with water was brought to a highly satisfactory result. The water is allowed to run into the spaces between the two shells as the vessels pass down the Thames; when the spaces are full the cocks are closed, and so remain until the arrival in the Tyne, when the water is pumped out by means of an apparatus provided for the purpose. This system allows the vessel to be ballasted without loss of time at either end of her voyage, and does not impair in the slightest degree her power of carrying coals. The introduction of the screw collier has revolutionized the coal-carrying trade, and has had a most beneficial effect upon commerce generally. Besides accomplishing the purpose for which it was designed, this class of vessel has been proved capable of rendering very important services to the Royal Navy. When, in the latter part of the year 1854, information reached this country that the commissariat department of our army in the Crimea had broken down, and that the salvation of our troops depended upon a rapid despatch of supplies, it was found that screw colliers were admirably adapted for the work, and the majority of them were temporarily taken out of the coal trade and employed in the transport service. The Government admitted on that occasion that screw colliers had proved to be more useful and economical than any other class of vessels they had employed.

In the year following the launch of the 'John Bowes,' namely, in 1843, the first iron vessel built on the Wear was released from its blocks. The Tees, with great energy and considerable success, followed the example, and on both those rivers, as we shall see presently, a very considerable trade in iron shipbuilding is carried on.

The first iron vessel for war purposes constructed in this district was 'The Terror,' one of the large iron-cased floating batteries designed during the Russian war to operate against Cronstadt. This vessel, of 2000 tons, 250 horse-power, carrying 26 sixty-eight-pounder guns, was built in three and a half months, and she would have been completed in three months had not the declaration of peace slackened the energies of our men, which, up to that time, had been maintained so nobly by their patriotic feelings.

It was in the building of this vessel that rolled armour-plates were first used. The demand for forged armour-plates was so great that the forges of the kingdom could not supply it, and recourse to rolling was unavoidable. At that time the largest plate mill was at Parkgate, and we accordingly employed Messrs. Beale and Co., the owners of Parkgate works, to roll the plates we required. To the use of these rolled plates, however, the Admiralty opposed itself; but we feeling convinced, by experiments which we made, that the rolled armour-plates were at least equal to the forged, invited the Admiralty to a trial of their efficiency.

We built a target 9 feet square, on a plan which we thought might be advantageously adopted for large vessels of war, and on the cellular principle. The cells we filled with compressed cotton, which we had found by experiment to be very effectual in stopping shot. On this target was a thin teak backing; on the teak were bolted one hammered and two rolled plates. The target was bolted on to the side of an old wooden frigate at Portsmouth, under the direction of Captain Hewlett. The first shot fired at it missed the target, went through both sides of the frigate, and, to my great astonishment, skimmed over the surface of the water for nearly a mile. The firing showed that whilst the hammered plate split and cracked to pieces, the rolled plates were not broken, only indented, and were superior to the hammered plate in every respect. Unfortunately the target was not firmly bolted to the vessel, and it sprung at each shot, so that the bolts which held the armour-plates were broken, and they fell into the sea.

A shot was then tried to test the resisting power of the compressed cotton, and it appeared to answer so well that Captain Hewlett advised a series of experiments to be made. The Admiralty were willing, but required us to provide the targets at our own expense. Having already spent upwards of £1000 on experiments for the good of the country, we declined this proposal; nevertheless we had proved to the Admiralty this important fact, that the rolled plates were superior to the forged, and they have since been universally adopted. We claim, therefore, for this district the honour of being the first to prove the strength and utility of rolled armour-plates, since known and spoken of in Parliament as "Palmer's Rolled Plates."

While on this subject of armour plates, I may perhaps be allowed, as the builder of the iron-plated frigate 'Defence,' to make a slight digression, in order to express an opinion upon the class of marine architecture to which that vessel belongs. The 'Defence,' although in every respect a strong ship, does not combine all the strength which, with the same weight of material, might have been obtained; and with respect to her model, it is my opinion that if she had had less rise and more floor, and so had drawn less water, she would have steamed faster, answered the helm quicker, and have proved in all respects more manageable and convenient. The Admiralty authorities, I know, do not agree in this view, and they are at the present moment spending a large amount of money in the national dockyards for the express purpose of building a class of vessels similar in construction to the 'Defence.' In my opinion it is, to say the least, very questionable policy for the Admiralty to speculate in this kind of shipbuilding. Private builders exerted themselves greatly in the production of armour-plated frigates for the Government; these vessels were produced in much less time than would have been consumed in the naval dockyards, and in the matter of cost the difference must be greatly in favour of vessels built by contract. It is surprising to see the tenacity with which the Admiralty cling to wooden ships, notwithstanding the most overwhelming proofs that it is time to adopt iron exclusively.

It was my desire to furnish the Association with accurate statistical details of the iron shipbuilding trade of these northern rivers, showing the quantity of iron consumed, the number of men directly employed, and the amount of tonnage launched per annum. But unfortunately my neighbours here, and on the Wear and Tees, with a few exceptions, were too much engaged to supply me with the statistics of their respective establishments. I have therefore estimated the several totals from such materials, aided by personal knowledge and experience, as I was able to obtain, and the following statement will, I think, be a pretty close approximation to accuracy:—

	Tons.
Estimated amount of tonnage of iron ships launched on the Tyne during the year 1862	32,175
Ditto ditto on the Wear	15,608
Ditto ditto on the Tees	9660
	57,443

The number of men annually employed in producing this quantity of tonnage, exclusive of those engaged in the manufacture of engines, was—

	Men.
On the Tyne	4060
„ Wear	2500
„ Tees	1550
Total	8110

The quantity of iron consumed during the same period in the construction of iron ships, was—

	Tons.
On the Tyne	22,540
„ Wear	9,360
„ Tees	6,760
Total	38,660

The amount of iron tonnage at present on the stocks in this district is as follows:—

	Tons.
On the Tyne	33,000
„ Wear	19,000
„ Tees	10,600
Total	62,600

But these statistics show us only the labour that is directly employed in the production of iron ships, and that, as we all know, is but a small proportion of the whole. It would indeed be difficult accurately to estimate the amount of labour that is indirectly concerned in this trade, as for instance in the manufacture of iron, the production of coals, the importation of timber, the construction of engines, and the supply of anchors, chains, sails, &c. Enough has been said, however, to prove that iron shipbuilding is one of the most important branches of industry in this great commercial and manufacturing district.

I may perhaps be allowed to describe very briefly the operations of my own firm, which, I trust, will prove of some interest, as showing the extent to which one establishment may be developed. In the first place, we obtain the greater portion of our limestone from our own mines. At a point on the coast ten miles north of Whitby, the ironstone seams crop out in the sides of the cliffs, and here we have formed the small harbour of Port Mulgrave, where vessels can ride in safety, and ship their cargoes with ease and expedition. Between the Tyne and Port Mulgrave some of our steamers run direct, making on the average four voyages per week, whilst others of a larger class call to load stone on their return voyage from London. At Jarrow the ore is delivered to the furnaces by means of the Armstrong hydraulic cranes, and mixed with ores from Cumberland, Devonshire, and Lincolnshire; thence it is passed to the mills, and from the mills to the shipyards. The number of men employed in these operations is upwards of 3500. The number of tons of iron consumed per annum in our yards and engine works is about 18,000 tons. The amount of tonnage launched during the year ending the 1st August was 22,000 tons. We have 15,000 tons in course of construction, and orders spread over a period for 40,000 tons more. Amongst

these latter are steamers of upwards of 3400 tons burthen, pronounced by their owners to be "the finest and most complete merchant steamers ever built." They are intended to bring cotton from the Southern States of America, so soon as the unhappy war in that country shall cease, and they will no doubt be but the pioneers of others of a similar class. One of these steamers is of sufficient capacity to carry 7000 bales of cotton, and it is estimated that, during one year, she will bring from New Orleans to Liverpool 38,000 bales. The crew of such a vessel consists of sixty hands, and it would require five sailing vessels of 1200 tons each, employing 130 seamen, to do the same work.

A consideration of the future of the iron shipbuilding trade opens out a vast field for speculation, but the ultimate result is not difficult to anticipate. We have seen with what success sailing vessels have been superseded by steamers in the coasting and coal trades, and we know that magnificent fleets of steamers, engaged in the postal and other services, are ploughing almost every known sea. As commerce increases, there will be few trades in which the employment of iron steamers will not be found of advantage. Most of the carrying trade to the Baltic and Mediterranean is already conducted in vessels of that class, and the sailing ships that cross the North Atlantic are being rapidly displaced by iron steamers. Their advantages in strength, speed, and capacity are so marked, that sailing vessels of timber must give way before them. Even the Admiralty, cautious and unyielding though it be, will have to abandon its "wooden walls" in favour of the stronger and more useful material—a material, too, that lies in rich profusion beneath our feet, and has not, like timber, to be purchased of other nations. The commercial men of this country have set the Admiralty a signal example of industry and enterprise. It is they who have made the experiments, and adopted the inventions that have established the maritime supremacy of this country; and it is owing to their energy that we find on every sea, in the shallow rivers of the East, and the deep broad waters of the West, English-built ships of commerce diffusing the benefits of free trade, and linking nations and tribes together in the bonds of amity and peace. The true source of our national greatness is to be sought in this wonderful development of our merchant navy. Other nations are entering into friendly rivalry with us, but the larger share of the carrying trade of the world will ever be secured to that country that can produce vessels combining the largest capacity with the utmost amount of economy and expedition in construction, and that can at the same time navigate those vessels with the greatest degree of skill and rapidity.

In conclusion, permit me to express the proud conviction I entertain that the mineral wealth of this district, and the skill and endurance of its workmen, whether on land or sea, will enable the locality that gave birth to an Armstrong and a Stephenson to maintain its character for maritime industry and enterprise, and to bear its full share in promoting the commercial greatness of the country.

On the Chemical Manufactures of the Northern Districts. By Thomas Richardson, *M.A., F.R.S.E.*; J. C. Stevenson, *F.C.S.*; *and* R. C. Clapham.

Salt.—Salt-works were formerly very numerous in this district, establishments having been formed at Howdon Pans, Hartley Pans, Jarrow, North and South Shields, and other localities. This trade was carried on by several

of the most wealthy families in the neighbourhood, in the beginning of the last century, and about 200 pans were employed in producing salt, which was extracted from sea-water and brine-springs. Shields salt was the most celebrated salt in the kingdom, and was produced in such quantities at South Shields as to give a character, and even a nomenclature, to the town, which to this day is divided into East Pan and West Pan Wards. The remains of a large hill are still to be seen, formed from the ash of the salt-pans. After a time, these ashes took fire, and Mr. R. W. Swinburne—to whom we are indebted for this information—states that the Chapter of Durham are in possession of a picture representing the burning hills at South Shields. The production of salt from sea-water in this locality has given place to that obtained from the brine-springs and rock-salt of Cheshire, and the fact illustrates what great changes take place in altering the *locale* of manufactures. A considerable quantity of white salt is still made, on the Tyne, from sea-water, in which rock-salt from Cheshire and Ireland is dissolved, in order to diminish the cost of evaporation. Two improvements have been successfully introduced in making white salt, which have the saving of fuel as their object. Mr. Wilkinson employs the waste heat of coke-ovens for this purpose; and Mr. Fryar dries whitening with the heat which escapes from his salt-pans.

Alkali (for this and the last century).—Towards the end of the last century two gentlemen, Mr. W. Losh and Mr. Thomas Doubleday, were engaged, unknown to each other, with a series of experiments on the best plan of converting common salt into carbonate of soda. These chemists appear to have used very similar processes; and when the late Lord Dundonald came to reside in the neighbourhood, he was soon on intimate terms with both parties. Both Mr. Losh and Mr. Doubleday tried numerous plans at his lordship's suggestion; but after spending upwards of £1000, Mr. Doubleday seems to have become tired of making an outlay which promised little or no result. The first plan tried was to effect the decomposition of common salt by means of oxide of lead, and to carbonate the caustic soda, while the insoluble chloride of lead was heated to form a yellow pigment, long known as Turner's yellow. Another process consisted in decomposing common salt by sulphate of iron. The resulting sulphate of soda was fluxed with coal, and the sulphide of sodium which was formed was carbonated with sawdust. This plan was also worked, some time afterwards, at an alkali manufactory situated near Blyth. Another process, which was tried, was founded on the mutual decomposition of common salt and sulphate of potash. This operation was always carried on by Mr. Losh and Mr. Doubleday whenever the price of the two potash-salts allowed a profit to be made, and the chloride of potassium was regularly sold to the Yorkshire alum-makers. Mr. Losh resided in Paris in 1791, where he acquired a knowledge of chemistry, and soon after his return home, a company was formed to manufacture soda at Walker. The original partners were Lords Dundas and Dundonald, Messrs. Aubone, and John Surtees, and John and William Losh. They obtained their salt from a brine-spring found in a coal-pit at Walker, and the heavy duty upon salt at that date, which was £36 per ton, was avoided by evaporating a concentrated solution of the brine-spring with sulphuric acid; thus making sulphate of soda, and not salt. Another plan adopted by Mr. Losh, to avoid the duty, was to add ground coke or ashes to the concentrating salt-pan before the salt was formed, and use it, in this damaged condition, for the manufacture of sulphate of soda. This was about the year 1796; and Messrs. Doubleday and Easterby, in 1808, commenced making sulphate of soda by decomposing the waste salts from the soap-boilers, which consisted chiefly of

common salt and some sulphate of soda. Their chief supply was obtained from the Messrs. Jamieson and other soap-boilers at Leith. They purchased their sulphuric acid at first, but between 1809 and 1810 they got the plans of chambers from Messrs. Tennant, of Glasgow, and erected the first chamber on the Tyne at Bill Quay. They imported the first cargo of sulphur from Sicily about the same time, and its arrival in the river excited great attention. At first, the Government returned them the import duty on this sulphur, which was used in making acid, and the present Mr. Doubleday remembers having received, at the end of the year, as much as £1500. This, however, only lasted some three or four years, when the duty was repealed. This firm, then trading under the name of Doubleday and Easterby, also erected the first platina retort for making rectified oil of vitriol. This retort cost them £700, and before long they had three retorts in operation. The alkali which they made was used, in the crude state, in the manufacture of soap, in which they were also engaged. In 1816, after the conclusion of peace, Mr. Losh returned to Paris, where he learned the details of the present plan of decomposing sulphate of soda, which he immediately introduced in his works at Walker, and thus may be said to have been the father of the modern alkali trade in this country. Mr. Doubleday gave the plans of his chamber, furnaces, &c., to the Messrs. Cookson when they commenced their alkali-works at South Shields. This trade has been developed in an extraordinary manner in this locality, where about 47 per cent. of the whole produce of the United Kingdom is now manufactured. The peculiar advantages of the district are also being recognized by the fact that the celebrated firm of Messrs. Tennant have purchased land with the intention of removing the greater part of their works from Glasgow to the banks of the Tyne*.

The following details will embrace a brief account of the source of the raw materials, and the various improvements which have been recently introduced:—

Source of Sulphur.—Until within the last few years, Sicilian sulphur was almost exclusively employed in this district for the manufacture of sulphuric acid,—the pyrites from Wicklow being the only other source of supply. This latter, however, was not sufficiently abundant to render the manufacturer independent of the great fluctuations which have recently taken place in the price of sulphur, on account of the demand consequent on the vine disease. During the last few years, the following additional sources of supply have been available:—1st, the Belgian; 2nd, Norwegian; 3rd, Spanish or Portuguese; 4th, Italian; 5th, Westphalian pyrites. 1. The Belgian pyrites has the advantage of being shipped at Antwerp at a moderate freight to the Tyne. It is a very hard, compact material, containing about 50 per cent. of sulphur, and therefore nearly approaches a pure bisulphuret of iron. The burnt residue from one manufactory on the Tyne (the Walker Iron Works) after being roasted in a lime-kiln, to burn off the small remaining portion of sulphur, is regularly used as an iron ore at the adjoining iron-works. It contains no copper, and from 3 to 5 per cent. of arsenic. 2. The Norwegian

* Charles Cooper, an overman at Walker Colliery, informs us that he was employed by Mr. Losh in 1798, and that crystals of soda were then manufactured and sold by Mr. Losh. The salt obtained from the brine-spring on the premises was evaporated in small lead pans, and was afterwards decomposed by litharge. The soda so produced was crystallized in small lead cones; and when it had stood sufficiently long to crystallize, the cones were turned upside down to run off the mother liquor. The crystallizing process was then only carried on in the winter months. Mr. C. Hunter, of Walker, further informs us that in 1816 he sold about half a ton of soda for Mr. Losh, to a Mr. Anderson, of Whitby, at £60 per ton.

pyrites is shipped at Levanger. It contains 44 per cent. of sulphur, is easily broken, and does not flux in the kiln. The quantity of copper it contains being less than 1 per cent., the burnt residue cannot be profitably smelted for copper. 3. The most extensively used pyrites is shipped from Huelva, in Spain, and Pomeron, in Portugal. The mines are situated on each side of the boundary between the two countries. They were most extensively worked in ancient times, but their recent development has arisen from the use of the ore as a source of sulphur. Containing only from 2 to 4 per cent. of copper, it was unable to compete with the richer ores which, from time to time, became available in different parts of the world; but the mining is now rendered profitable in consequence of the sulphur having acquired a value as well as the copper. The percentage of sulphur varies from 46 to 50. The practical difficulty in burning this ore, namely, its great fusibility at the point where the combustion of the sulphur gives rise to considerable heat, has been overcome by the adoption of kilns, first used in Lancashire, in which the area of the surface is large in proportion to the weight of the charge of pyrites. The use of cupreous pyrites has led to the introduction of the manufacture of copper on the Tyne, which will this year amount to between 700 and 800 tons. The ordinary process of smelting is employed; but the moist method is also being tried, the advantage being, that by this method all the ingredients of the mineral are utilized, the oxide of iron making an ore of similar quality to hematite. The smelting process, however, is still preferred in the large manufactories. In 1860, several cargoes of an ore containing free sulphur imbedded in gypsum were imported from the island of Milo, in the Archipelago. From the small quantity of sulphur contained in it (19 up to 24 per cent.), great difficulty was experienced in burning it, except in large masses. Subjoined is an analysis of one parcel of it:—

Sulphur	24·00
Gypsum	62·20
Sand, &c.	6·00
Water	7·00
	99·20

Still more recently, Professor Ansted has discovered a deposit of free sulphur in Corfu, of which he has been kind enough to forward a sample; but we believe it has not been used in commerce. When sulphuric acid is wanted quite free from arsenic, Sicilian sulphur must be used. So largely has pyrites displaced sulphur in the production of sulphuric acid, that in 1862 only 2030 tons of sulphur were consumed, against 72,800 tons of pyrites; and, reckoning the above quantity of sulphur as equivalent to 4500 tons of pyrites, it appears that 77,300 tons of pyrites are annually used for the manufacture of sulphuric acid, along with 2500 tons of nitrate of soda. Assuming a produce of 120 per cent. on the pyrites, this is equal to a production of 92,760 tons of sulphuric acid, calculated as concentrated. This quantity of sulphuric acid is nearly all consumed where it is made, for the manufacture of other chemicals, such as soda and manures, the quantity sold being 6440 tons; but this might be more correctly described as consumed in other works, for the quantity sent to a distance is very small. Four-fifths of the sulphuric acid is used for the decomposition of common salt.

Salt and the Alkali trade.—The ordinary Cheshire salt is almost exclusively used for the manufacture of alkali, the exception being in one

manufactory where the waste heat of coke-ovens is utilized in evaporating the liquors formed by dissolving rock-salt. Nearly all the salt used in the alkali-works is carried by canal to Hull, Goole, or Grimsby, whence it is brought to the Tyne at a nominal freight, generally by foreign vessels, that take it as ballast when coming to the Tyne for an outward cargo of coals. This is the only practical result of the repeal of that portion of the navigation laws which prevented foreign ships carrying cargoes coastwise. The annual consumption of common salt in the district is 90,000 tons, requiring 73,800 tons of sulphuric acid, and producing 100,000 tons of dry sulphate of soda. The whole of this quantity is used in the manufacture of alkali. A few hundred tons are consumed in the glass manufacture, but are omitted here, as no account has been taken of the sulphate of soda made from the nitrate of soda in the sulphuric-acid process. The alkali is produced in the four forms of—1, alkali or soda-ash, 43,500 tons; 2, crystals of soda, 51,300 tons; 3, bicarbonate of soda, 7450 tons; 4, caustic soda, 580 tons. The manufacture is so well understood, that only local peculiarities and recent improvements need be noticed.

Alkali.—All the Tyne soda-ash is fully carbonated, sawdust being generally used in the furnace for this purpose, so that it contains merely a trace of hydrate of soda. The greater part of it is also refined by dissolving, settling, evaporating, and calcining, thus producing an article of great whiteness and purity.

Caustic Soda.—This manufacture is, as yet, quite in its infancy in this district. In Lancashire very large quantities are made from the "red liquors" which drain from the soda salts. These liquors always contain caustic soda, sulphuret of sodium, and common salt. In Lancashire, where a hard limestone is used for balling, the percentage of caustic soda is large, while the sulphuret exists in small proportion, and is easily oxidized. It would seem that the London chalk, which is used here, produces a lime chemically much less energetic, forming less caustic soda, and holding sulphur more loosely in combination. Consequently the Tyne red liquors require a very large quantity of nitrate for their oxidation, and yield so little caustic soda that this process has been abandoned in favour of the well-known method of boiling a weak solution of alkali with lime. This has the advantage, however, of producing a richer and very pure article, sometimes as strong as 74 per cent.

The improvements (besides such as have been already noticed) which have been introduced into the alkali trade, since the last meeting of the British Association in Newcastle, may be divided into those which have been generally adopted, and the special improvements of individual manufacturers. 1st. Economy of labour has been attained by using larger furnaces, in which a workman can manipulate a larger charge with less toil, and by various other appliances purely mechanical. 2nd. Economy of fuel has been largely attained by the application of the waste heat and flame from the ball furnaces to the surface-evaporation of the tank or black-ash liquor. Formerly, this was evaporated in hemispherical cast-iron pans, each with a fire below. 3rd. Economy of water and fuel by the adoption of the circulating tanks for lixiviating balls, first introduced at Glasgow by the late Mr. Charles Tennant Dunlop. They are so arranged as regards their connexions with one another, that water runs into the tank which has been most nearly exhausted, and liquor of full strength runs off the tank which has been most recently filled. The balls are always under the surface of the liquor, and thus escape the partial decomposition and consequent formation of sulphuret, which resulted

from the balls being subjected to successive washings and drainings. 4th. Use of cast-iron decomposing-pans. 5th. Gay-Lussac's process for recovering and using again the waste nitrous acid in the manufacture of sulphuric acid has been adopted by several manufacturers; others consider that the expense of the erections and of working the process may be better applied in providing an additional amount of space in the leaden chambers. The special improvements are:—1st. Revolving ball furnaces, invented by Messrs. Elliott and Russell, of St. Helen's, and used in the Jarrow Chemical Works. 2nd. In the Walker Alkali Works, the waste gas (carbonic oxide, &c.) from the blast-furnaces of the adjoining iron-works is conveyed by flues to the evaporating and calcining furnaces. The advantage obtained is not only economy of fuel, but a hot flame free from smoke and dust, and dispensing with the stoker's labour and tools. It is found very useful for regulating the bottom heat of the cast-iron pan in which salt is decomposed. The carbonic oxide is, however, found not to burn very well in the presence of muriatic-acid gas.

Hyposulphite of Soda.—The manufacture of hyposulphite of soda has largely increased of late years, and we believe it was not made upon the Tyne previous to 1838. In 1854 the produce only amounted to 50 tons per annum. It has gradually risen to 400 tons per annum. In addition to being used in photography, it is largely employed as an "anti-chlor" in paper-making; and the markets of Europe and America are chiefly supplied from the Tyne. In 1852 Mr. W. S. Losh obtained a patent for the manufacture of hyposulphite of soda from soda-waste, which has been the means of greatly lessening the price, and extending its application in the arts. On account of its great stability, hyposulphite of soda has nearly superseded the use of the older salt—sulphite of soda—as an "anti-chlor," the latter being chiefly confined to sugar-refineries as a deoxidizer. Dr. Jullion has recently obtained a patent for the production of hyposulphite of lime, to be used as an "anti-chlor," but it has not yet been introduced in commerce, the apparatus for its manufacture, in course of erection at the Jarrow Chemical Works, not being completed.

Hydrochloric Acid.—In the decomposition of common salt vast quantities of hydrochloric acid are necessarily produced, and it is an important question for chemical manufacturers to apply the best means for its condensation. Since the visit of the Association in 1838 few branches of manufacture have received more attention, and there are few in which greater improvements have been effected than in condensing muriatic-acid gas; and this has arisen not only on account of the necessity of preventing injury to agriculture, so that heavy claims for damage might be avoided, but also in consequence of the commercial value attached to hydrochloric acid in the production of bleaching-powder, bicarbonate of soda, oxychloride of lead, and other products. The methods generally employed in condensing are well known, and we shall only allude to some of the improvements practically applied. The drying-furnace generally used is called an "open furnace," to which the heat of the fire is directly applied; and we believe that the greatest difficulties in the way of a perfect condensation, in former times, arose from the gases from this furnace. The heat required to drive off the gas from the crude sulphate of soda is very great, so that when the gases arrived in the condensers, it was found difficult to absorb them, even when a very large quantity of water was used; and the muriatic acid which was thus produced was of so low a strength, as to be, commercially, almost useless. In former years, also, the draught through the condensers was always obtained by a connexion with a high chimney; but in some of the works this plan is now abandoned,

and the whole of the vapour or gas which escapes passes through a 12-inch pipe always open to view. At present, these gases are conducted through long flues or pipes and cooling-shafts, and on entering the foot of the condensers the heat is reduced to about 140° Fahr., at which point the gases easily condense, and a strong acid is obtained at the same time. A rather different method has been pursued for some time at Messrs. C. Allhusen and Sons' works. Instead of the heat from the fire being conducted directly on to the drying materials in the furnace, a "close" furnace is used, in which the flame from the fire passes over a brick arch and under the bed of the furnace, and not in immediate contact with the materials; this furnace has no connexion with a chimney for its draught, and the gases from both the pan and dryer pass into one condenser. The hydrochloric acid passes off from the furnace unmixed with the smoke from the fire, and at a lower temperature than the ordinary method, and is consequently more easily condensed, and obviates the necessity of long flues or cooling-shafts. Messrs. Allhusen and Sons have given us the following results of some recent experiments with this kind of furnace. The charge of salt generally used, was 8 cwt., the moisture varied from 6 to 9 per cent., and the sulphate of soda contained from 1·75 to 2·25 per cent. of undecomposed salt.

	Salt undecomposed.	Moisture per cent.	Theoretical weight of acid.	Acid obtained.	Loss per cent.
1st experiment	1·75	7·0	502·0	495·06	1·4
2nd ,, ...	1·70	7·0	498·0	498·00	1·8
3rd ,, ...	2·25	7·0	498·0	484·08	2·6
4th ,, ...	1·80	7·0	498·0	490·04	1·6
5th ,, ...	1·70	7·0	498·0	485·00	2·8
				Average....	2·0

As a further instance of the care that is now bestowed in condensing, we append also the result of some recent experiments conducted at the Walker Alkali Works to ascertain the actual quantity of muriatic acid condensed. The daily produce was conducted into large cisterns prepared for the purpose, and the strength, depth, &c., was carefully ascertained. The salt used was also tested daily for moisture and impurities, such as sulphates, sand, &c. The former was found to average 6 per cent., and the latter $1\frac{1}{2}$ per cent. during six months' trial, thus leaving 92·5 per cent., $NaCl = 57·7\,HCl$ in 100 parts of salt used.

The crude sulphate of soda produced was also daily tested for common salt left undecomposed, which is deducted below:—

		HCl.	Test of Sulphate.
January	100 parts of salt gave....	58·3	25·9
February....	,, ,, ...	53·0	2·24
March	,, ,, ...	54·2	2·25
April	,, ,, ...	57·4	1·14
May	,, ,, ...	58·4	2·98
June	,, ,, ...	53·9	2·12
	Average HCl	55·8	2·45
	HCl left in sulphate of soda	1·52	
		57·32	
	Loss per cent.	0·38	
		57·70	

A patent was obtained by Mr. R. C. Clapham, in 1860, for the use of the weak acid in the place of water for condensing, which has been successfully carried out in the above works; and it will thus be seen that the whole of the acid produced was obtained and calculated without difficulty. Muriatic acid is not entirely free from impurities; and, on account of its containing arsenic, iron, sulphuric acid, &c., it is not applicable to all purposes. The total quantity of hydrochloric acid produced is about 180,000 tons per annum.

Manganese.—Manganese is imported from Germany and Spain, but it is chiefly from the latter country that the richest ores are now obtained. It is found in hills consisting of schistose rock, which sometimes rise to a height of 800 feet from the level of the plain; but it is also found in "pockets," in which case it is quarried by picks, and occasionally gunpowder is used. The quality of the ore varies from 50 to 90 per cent. peroxide; and to obtain the richer ore, men and boys are employed to break and sort it. It is then put into sacks and carried a distance of 20 to 35 miles, on mules' backs, to the ports of shipment in the Mediterranean. The richest ores are obtained at Calanas, in the province of Huelva, 30 miles north of the ancient Roman fishing-town of Huelva. We are indebted to Mr. S. F. Gething for this information, who also informs us that he imported to the Tyne, in 1857, the first cargo of this kind of manganese. Manganese ore frequently contains peroxide of iron, copper, cobalt, titanium, &c.; but no means have hitherto been taken to separate them. Manganese is used in the manufacture of glass, iron, and of bleaching-powder; and for the latter it is imported to the extent of 14,400 tons annually. Several patents have been taken out for the recovery of the manganese from the waste chloride of manganese solutions, but generally with indifferent success. The most successful, however, is the process of the late Mr. Charles Dunlop, of Glasgow, in which the manganese is precipitated as a carbonate, and finally oxidized. This patent has been profitably worked at St. Rollox, in Glasgow, and has, to some extent, superseded the use of native manganese. Still more recently, a patent has been obtained by Mr. Clapham for the separation of the free hydrochloric acid contained in the waste manganese solutions, and for its application in the manufacture of bleaching-powder.

French Limestone, locally called 'Cliff,' is imported as ballast from the Seine, and also from the coast of France, to the extent of about 14,000 tons annually. It forms part of the upper chalk-bed in the secondary deposits, and is nearly pure carbonate of lime; and although very like chalk in its appearance, differs from it to some extent in being compact, harder, and less susceptible of retaining water. It is always used in this locality, in preference to other limestone, for making bleaching-powder.

Bleaching-powder.—Since 1831, the method pursued in the manufacture of bleaching-powder has entirely changed, and the quantity made has far more than doubled. At that time it was made by the decomposition of manganese and common salt with sulphuric acid, which was rather a costly process, and the price was about £28 per ton. It is now manufactured from what was, at one time, the waste muriatic acid referred to above, and the price has been reduced to one-third. During the last few years the demand for bleaching-powder has been increased, partly on account of the extensive use of Esparto grass from Spain in the manufacture of paper, which has been found to require a large quantity of chemicals to bleach it. The quantity of bleaching-powder now made is 11,200 tons per annum.

Soap.—The first soapery in this locality was begun by Messrs. Lamb and

Waldie, about the year 1770, at the Westgate, Newcastle, whence it was removed to the Close. The works were purchased by Mr. Thomas Doubleday in 1775, and continued under the firm of Doubleday and Easterby until the year 1841. Other manufactories were built in Sandgate and at the Ouseburn, all of which have been abandoned. Very little hard soap was made until the end of the last century; Castile soap only was used. Up to 1770, soft soap was chiefly used for both domestic and manufacturing purposes. The chief improvements introduced have been the use of palm oil, bleached by Watts's process, and the manufacture of the ley by boiling the alkali with the lime, instead of the so-called "cold process." The total quantity now manufactured exceeds 6000 tons per annum. The prices of the raw materials at the present time are as follows:—tallow, first sort, T. C., 43*s*. 6*d*.; fine American resin, 36*s*. to 39*s*.; best yellow soap, 33*s*. to 35*s*.; best mottled soap, 33*s*. per cwt.

Prussiate of Potash.—The first attempt to manufacture any compound of cyanogen in this district was made in the beginning of the last century, by a Jew, in Oakwellgate, in Gateshead. He afterwards removed his apparatus to Corbridge; but, failing in producing a saleable article, he discontinued the operation, which was taken up by a Mr. Simpson, who ultimately succeeded in perfecting the process in works erected at Elswick. Mr. Simpson manufactured Prussian and other kinds of blue colours; and at his death the manufacture was removed to Heworth, where the Messrs. Bramwell have carried on the works since 1758. Prussian blue was the only form in which the cyanogen was produced, from which prussiate of potash was afterwards manufactured. This salt was not known in commerce in a crystallized form, however, till about the year 1825, when the price was 5*s*. per pound. The price has now fallen to 11½*d*. Mr. Bramwell has introduced various improvements in the manufacture of this salt, employing close pots, in which the fused materials are worked by machinery, and substituting sulphate of potash for the more expensive potashes; but notwithstanding the application of every chemical and mechanical appliance, and the low prices at which the prussiate of potash is sold, the demand has fallen off, and at present only two tons of yellow prussiate and ¾ ton of red prussiate are manufactured weekly. The decline in this trade has arisen partly from the American civil war, and partly from the introduction of the aniline colours. The celebrated attempt, in 1844, to produce cyanogen from the nitrogen of the air, was made at these works; and although the efforts of Mr. Bramwell and his friends were perfectly successful in a chemical point of view, these gentlemen were induced to abandon the process as a manufacturing operation.

Alum.—The first alum-works established in England were erected at Guisborough in 1460, by Sir Thomas Challoner, who brought over a workman from France to carry out the then secret process, the monopoly of this trade being in the hands of the Pope. The works were subsequently decreed to be a royal mine, and passed into the possession of the Crown. They were afterwards farmed to Sir Paul Pindar, at a rental of £15,000 per annum. He employed about 800 persons, and made large profits, his monopoly enabling him to keep up the price to £26 per ton. The Long Parliament restored the mines to the original owners, and at the Restoration not less than five manufactories were in operation. The process is well known; but potash-alum (formerly the only alum made) is now only produced at the Loftus Works, all the other manufacturers employing the cheaper sulphate of ammonia. From the mother liquors large quantities of an impure sulphate of magnesia are obtained, which are partly refined and partly consumed as a manure, mixed

with other substances. Alum and sulphate of alumina are also made from sulphuric acid and clay or shale, but the quantities are not very large. The quantities produced annually are as follows:—Alum, &c., 4000 tons; rough Epsoms, 1800 tons. Some improvements in the details have been introduced to economize labour and save materials. The precipitation of the iron from aluminous liquors by means of prussiate of iron was first employed here by Messrs. Lee and Co.; and the Guisborough Alum Company have introduced an aluminous cake, containing sulphate of magnesia, which has been found to answer very well in dyeing certain colours, as browns, blacks, &c., and in the manufacture of all kinds of coarse paper.

Epsom Salts.—The abundant supply of magnesian limestone on the coast of Marsden, three miles south of the Tyne, and at other places in the county of Durham, has for many years sustained the manufacture of sulphate of magnesia on the Tyne. The mineral is a tolerably pure double carbonate of lime and magnesia, containing about 21 per cent. of magnesia. The following is an analysis by Mr. Clapham:—

	Per cent.
Silica	10·00
Alumina	1·60
Oxide of iron	0·50
Carbonate of magnesia	35·33
Carbonate of lime	52·50
	99·93

The process formerly employed was to calcine the limestone, and wash it repeatedly with water, by which, however, the lime is only imperfectly removed, the residue being dissolved in acid and crystallized. The principal source of sulphate of magnesia for many years past has been the rough Epsoms obtained from the residual mother liquors of the Yorkshire Alum Works. In these salts protoxide of iron replaces a variable proportion of magnesia, forming a double salt, and an excess of sulphuric acid is always present.

The following is an analysis of rough Epsom salts by Dr. Richardson:—

	Per cent.
Sulphuric acid	32·26
Magnesia	15·35
Protoxide of iron	1·73
Oxides of nickel and cobalt	0·12
Lime	0·09
Alumina	1·33
Potash	0·83
Water	48·29
	100·00

Formerly these salts were mixed with washed magnesian lime, and then calcined in order to peroxidize the iron. It is found, however (as first suggested by Dr. Richardson), that calcination is unnecessary when the solution is sufficiently diluted, and when space is provided in the precipitating-tank for the bulky precipitate of protoxide of iron which is formed by the gradual addition of magnesian lime. This is probably the only chemical

manufacture of the district, with the exception of prussiate of potash, which has greatly fallen off in extent, a more rational system of medicine having diminished the use of purgatives, and reduced the demand for Epsom salts to about one-third of what it was twenty years ago. The annual production is still 1500 tons, two-thirds of which are made from the rough salts.

Carbonate of Magnesia.—This compound has long been produced in this district, where it was formerly, and is still to a limited extent, manufactured from the mother liquors of the salt-pans known as Bittern, to which carbonate of soda is added to precipitate the magnesia in the form of carbonate. This old plan has been largely superseded by the elegant process of the late Mr. H. L. Pattinson, which consists in submitting calcined magnesian limestone to the action of carbonic acid and water, under pressure. The magnesia dissolves out as bicarbonate of magnesia, from which the neutral carbonate of magnesia is precipitated by the application of heat. The quantity manufactured is said to be about 250 tons per annum.

Superphosphate of Lime.—The manufacture of this article was commenced at Blaydon in 1844, by Dr. Richardson, soon after the publication of Liebig's celebrated report on agricultural chemistry. Various materials are employed as the source of phosphate of lime, viz. bones, bone-ashes from South America, exhausted animal charcoal from the sugar-refineries, coprolites from Suffolk and Cambridgeshire, phosphorite from Spain, Sombrero guano, &c. Improvements have been introduced in the manner of mixing the acid with these substances, in drying, and in the riddling of the superphosphate. The quantity produced amounts to between 15,000 and 16,000 tons per annum.

Pearl-hardener.—This article has only recently been manufactured here, and its introduction is due to Dr. Jullion, who has applied it to the hardening of paper. It is produced by precipitating hydrated sulphate of lime from a perfectly pure solution of chloride of calcium by means of sulphuric acid. Great care is taken in its preparation, and it is being generally introduced among the manufacturers of paper. The quantity made is said to be about 2000 tons per annum.

Sulphate of Iron.—The first manufactory for the production of green copperas in England was founded about the year 1579, when one Matthew Falconar, a Brabanter, "did try and draw very good brimstone and copperas out of certain stones, gathered in great plenty on the shore, near unto Minster, in the Isle of Sheppey." Mr. Thomas Delaval commenced to manufacture copperas at Hartley about the year 1748, but he subsequently sold the manufactory to his brother, Lord Delaval, and by an Act of Parliament, 11th of George III., 1771, power was given to Sir Francis Blake Delaval to grant to Sir John Hussey Delaval, in fee simple, all the copperas-works then and there existing; which may enable us to form some idea of the importance then attached to this manufacture. The late Mr. Barnes and Alderman Forster erected the first copperas-works on the Tyne, at Walker, in 1798, which are still in operation. The quantity at present manufactured is about 2000 tons per annum, and the process is still the same; but Mr. Thomas Barnes has applied the refuse crystals to a novel purpose. This refuse was, and is, generally thrown away; but Mr. Barnes uses it as a manure on his farm, on the thin soil which lies on the magnesian limestone. He finds that the depth of the soil is gradually increasing by the disintegration of the rock, and that the more he uses, the more satisfactory are the results. The beneficial effect of the copperas is doubtless partly due to the natural decomposition of the carbonate of lime with the sulphate of iron, and partly to the action of the peroxide of iron on the organic matter of the soil.

While being constantly renovated, a supply of oxygen is provided in a solid form by this hydrated oxide of iron.

Venetian Red.—The manufacture of this article has long been carried on in this neighbourhood, and is noticed here, as it is so closely related to green copperas. It is made by calcining a mixture of copperas and some native hydrated oxide of iron, chalk, and gypsum. The calcined mass is levigated and dried. About 4000 tons per annum are manufactured on the Tyne, and the price varies from £4 10*s*. to £5 per ton.

Sulphate of Copper.—This salt was formerly produced by roasting old copper in a reverberatory furnace, and then dissolving the oxide in sulphuric acid, but it is now obtained in carrying out Longmaid's process for decomposing common salt by means of cupreous pyrites. The quantity made is about 100 tons per annum, which is all produced at the works of Messrs. J. and W. Allen.

Resin Size.—This article is manufactured according to a patent obtained by Mr. W. S. Losh, and is intended to produce a size suitable for paper-makers, and to supersede the old size in ordinary use, which consists of alum, resin, and soda-ash. Its manufacture has, however, been only partially developed, and not more than 100 tons yearly are produced; but a new and cheap size, which can be prepared ready for the use of the paper-trade, is, we think, a step in the right direction, and the theory of the sizing of paper is a field still open to chemists.

Lamp-black.—The manufacture of lamp-black, we believe, is peculiar to this locality, and it is produced from bituminous coals. These coals are slowly burnt, at a dull heat, and with as small a supply of air as possible. The smoke is conducted into brick chambers, into which a jet of steam or water is passed, to assist in the better formation of the lamp-black. The quantity made is about 1200 tons annually.

Grease.—This product is made to the extent of 2800 tons annually. It is chiefly produced from the distillation of resin, and in a locality like Newcastle, surrounded by extensive collieries and works, the consumption is considerable. Since the American war the price has been much affected, and, we are told, has advanced from £8 or £9 per ton to £22 per ton.

Chemical Products of Gas-works.—The quantity of coal used in the manufacture of gas on the three northern rivers, the Tyne, Wear, and Tees, amounts to about 100,000 tons.

The products obtained are as follows:—

875,000,000 cubic feet of gas	£113,000
53,000 tons of coke	10,000
23,800 gallons of crude naphtha	2,800
309,000 gallons of creosote oil	1,250
3,560 tons of pitch	3,130
600 tons of sulphate of ammonia....	9,000
	£139,180

The sulphate of ammonia is manufactured direct from the gas-water, in the following manner:—A large cylindrical boiler is filled two-thirds full with the gas liquor, and gently boiled. The gaseous products and steam are conducted into a mother liquor, from a previous operation, which is kept slightly acid. When no more ammonia comes over, a quantity of milk of lime is added to the boiler and a strong heat applied, until the colouring matters cease to be disengaged. The gaseous products are collected as before,

and the colouring matters are skimmed off the surface of the liquor. The boiling is then moderated, and during the whole operation a stream of acid is supplied to the cistern. The sulphate of ammonia salts out, and is fished up into baskets to drain, when it is ready for the market.

Cement.—The manufacture of this material on a large scale in this district is of comparatively recent origin. A small quantity of cement has long been made on the Yorkshire coast, near Whitby, where a peculiar mineral is found in the alum-shale, called the "cement stone." This mineral has been analyzed by Dr. Richardson, who found it to contain—

Clay insoluble in acids		18·41
Consisting of silica	12·24	
,, of alumina	6·17	
Alumina soluble in acids		6·89
Oxide of iron		0·54
Lime		37·68
Magnesia		5·20
Soda and potash		traces
Organic matter		1·45
Carbonic acid and water		29·62
		99·79

About 20 cwt. of this mineral is found in every 60 tons of shale, and the greater proportion is sent to Hull, where it is manufactured into a cement, sold under the name of Mulgrave cement.

The mineral is burnt in small open kilns, and afterwards ground to a fine powder.

The production of cement on a large manufacturing scale dates from the establishment of the works of Messrs. T. C. Johnson and Co., in 1856. This firm manufactures Portland cement, Roman cement, Keene's marble cement, and plaster of Paris; and they have recently introduced improved machinery for the more perfect levigation of the raw materials, by which the subsequent chemical action is much facilitated.

Portland cement is very extensively used in this country, in France and Germany, for dock works, basins, fortifications, and for fronting houses in imitation of stone. It is also used for coating the inside of all first-class iron ships. The rivets are carefully coated, and are thus protected from the corrosive action of the bilge-water. It has been found of equal service in sugar-carrying vessels, where the leakage of the molasses exercises a very corroding action.

Roman cement is prepared by calcining Septaria in open kilns, and afterwards grinding the burnt material in horizontal stoves. It is used either alone or mixed with an equal volume of sharp sand.

Keene's marble cement is made by soaking calcined gypsum in a solution of alum, and then recalcining the mass at a dull red heat. This recalcined material is then ground and sifted. It is only used for internal work, such as floors, skirtings, walls, &c. It is largely employed in London in churches and club-houses; it rapidly dries after being applied, and may be papered or painted in two days. When dry, it is so hard that a nail cannot be driven into it. Two qualities are made, one of which can be polished in imitation of marble, while the other is used as a ground for painting: when different colours are introduced, a superior scagliola is formed.

The quantities manufactured per annum are as follows:—

	Tons.		Casks.
Portland cement	10,000	or	50,000
Roman ,, ...	350	,,	2,450
Keene's ,, ...	50	,,	350
Plaster of Paris	200	,,	2,000

The present prices are—

Portland cement	8s. 6d.	per cask of	430 lbs.
Roman ,, ...	7s. 6d.	,,	336 lbs.
Keene's ,, ...	14s. 0d.	,,	336 lbs.
Plaster of Paris	30s. 0d.	per ton.	

Quantities and Prices of Raw Materials used in Local Chemical Manufactures.

	Tons.	Price per ton. £	s.	d.	Value. £	s.	d.
Sulphur (included as pyrites)	72,800	1	10	0	99,200	0	0
(Copper value not included.)							
Salt	90,000	0	15	0	67,500	0	0
Nitrate of soda	2,500	14	15	0	36,875	0	0
Chalk	144,000	0	2	6	18,000	0	0
Coals........................	323,000	0	3	9	60,562	19	0
Manganese	11,400	4	0	0	45,600	0	0
Rough Epsom salts	1,500	2	5	0	3,375	0	0
Magnesian limestone	700	0	3	6	122	10	0
French limestone..............	14,000	0	4	6	3,150	0	0

Quantities and Prices of Finished Products.

	Tons.	Price per ton. £	s.	d.		Value. £	s.	d.
Alkali..................	43,500	8	10	0		369,750	0	0
Crystals of soda	51,300	4	15	0		243,675	0	0
Bicarbonate of soda	7,450	12	0	0		89,400	0	0
Caustic soda	580	18	0	0		10,440	0	0
Hyposulphite of soda......	400	25	0	0		10,000	0	0
Oil of vitriol	6,440	6	0	0		38,640	0	0
Epsom salts	1,500	7	5	0		10,875	0	0
Bleaching-powder	11,200	9	0	0		100,800	0	0
Soap	6,000	34	0	0		204,000	0	0
Yellow prussiate of potash..	105	0	1	0	℔ lb.	11,760	0	0
Red ,, ,, ..	40	0	2	6	℔ lb.	11,200	0	0
Alum	4,000	7	0	0		28,000	0	0
Carbonate of magnesia	250	30	0	0		7,500	0	0
Superphosphate of lime	15,000	5	0	0		75,000	0	0
Pearl-hardening	2,000	10	0	0		20,000	0	0
Sulphate of iron..........	2,000	3	0	0		6,000	0	0
Venetian red	4,000	5	0	0		20,000	0	0
Sulphate of copper	100	35	0	0		3,500	0	0
Resin-size	100	7	0	0		700	0	0
Lamp-black	1,200	7	0	0		8,400	0	0
Grease	2,800	8	0	0		22,400	0	0
Cements	12,000	2	0	0		24,000	0	0

On the Local Manufacture of Lead, Copper, Zinc, Antimony, &c. *By* T. Sopwith, *F.R.S., and* T. Richardson, *M.A., F.R.S.E., &c.*

Lead.

The lead-mining districts of the North of England are chiefly situated in or near the centre of that narrow portion of Great Britain which is formed by the counties of Northumberland, Durham, Cumberland, and Westmoreland, and may be considered as being nearly in the central portion of the whole island, being situated nearly midway in its length from north to south, as well as from east to west, between the German Ocean and the Irish Channel. Under the level lands which lie near to the eastern and western coasts, the upper portion of the carboniferous series of rocks contains numerous and valuable beds of coal. From beneath these coal-strata the "lead-measures," as they are locally termed, that is to say, the several beds of limestone and other rocks in which veins of lead-ore are chiefly found, gradually rise in a westerly direction, with an inclination exceeding that of the general rise of the surface, until they basset or crop out at the surface over a wide range of country, reaching their highest elevation at the mountain of Cross Fell in Cumberland, and other adjacent fells or mountain moorlands which extend in a north and south direction so as to form a western limit to the lead-mining districts. The strata which extend between the outcrop of the lowest of the coal-strata and the Cross Fell ridge of mountains are well known in the district as the carboniferous or mountain-limestone formation—so called from the abundance of coal so nearly associated with them, and from the numerous beds of limestone which prevail. These lead-mining strata lie nearly midway in the series of formations which are known in England, being as much below the tertiary beds of the south-east part of the island as they are above the Silurian rocks on the borders of Wales. A lofty range of elevated land extends from the borders of Scotland to Derbyshire, occupying from twenty to thirty miles in width of the middle portion of the north of England. In many parts of this range of hills are extensive lead-mines, which may be classed as follows:—

1st. Mining districts connected with the river Tyne and its tributaries—the Nent, East and West Allen, and the Derwent; Alston Moor, in the county of Cumberland; East and West Allendale, in the county of Northumberland; Blanchland, and Derwent Valley, in the same county. In addition to these, which form, as it were, distinct mining territories of considerable extent, other valuable mines in detached places have been discovered, and are extensively worked in the valley of the Tyne. 2nd. The extensive mining districts of Weardale, in the upper part of the valley of the river Wear, and its tributary valleys of Burnhope, Kilhope, Wellhope, Ireshope, Rookhope, &c. 3rd. Another extensive district in Teesdale, in the upper part of the valley of the river Tees, the mines being situated chiefly in the county of Durham, and partly in Yorkshire, worked by the London Lead Company.

The geographical position of these districts may be readily understood by referring to ordinary maps of this part of England, and by assigning to the upper part of the rivers Tyne, Allen, Wear, and Tees an area extending about twenty miles from their respective sources, and in the Derwent a range of about ten miles from its source. This would roughly indicate the position of the principal mines.

In any view of the history of mining it is impossible to overlook its connexion with geological conditions on which the very existence of the mine

depends. The mind is thus carried back to a remoteness of time for which an adequate expression has not yet been defined. The deposition of regularly stratified rocks over a large area of country exhibits proofs of gradual progress, extending over enormous periods of time. Midway in this vast period we find, in certain parts of the North of England, evidences of volcanic action, which has interposed basalt among the strata of sandstone, shale, and limestone. The results of this protrusion not only affect the subterranean operations in mines; they also appear prominently at the surface, and give rise to some remarkable features of the scenery. The "Whin Sill," as it is locally termed, interrupts the gradual flow of the river Tees by a barrier over which that river falls at High Force, near Middleton-in-Teesdale, and it is the cause of the romantic cataract called the Caldron Snout, near the source of that river. Precipitous cliffs of basalt, near Holwick, were formerly connected by a chain bridge, one of the first, if not the earliest, of that construction in Europe. The same overflowing of basalt which occasions these and other striking features of landscape scenery in Teesdale extends in a north-easterly direction, and occasionally forces itself on the attention by the manner in which it seems to have invited the erection of works of art: this rock by its greater hardness having withstood the abrading action which wore away the softer rocks, presents a firm foundation for buildings designed to be as strong as possible. Thus, for a considerable distance along the line of the Roman Wall, we find the direct course from Chesters to near Haltwhistle forsaken, and the wall built on the summit of precipitous crags of basalt. The pleasure-grounds of the Duke of Northumberland at Ratcheugh, near Alnwick, afford an example of the protrusion of this rock. Dunstanborough Castle, Bamburgh Castle, and Holy Island Castle may be mentioned as interesting places on this account. But the underground occurrence of basalt concerns still more nearly the practical operations of the miner, and involves much costly labour.

Old writers on mines and mining were seldom content to rest with a less remote antiquity than creation itself; and it curiously marks the state of geological science even so late as 1670, when Sir John Pettus wrote his 'History, Laws, and Places of the Chief Mines and Mineral Works in England, Wales, and the English Pale in Ireland.' The hills and dales were treated as having been watery billows formed by the breath of the Almighty into hills and valleys, which, says the writer, "have ever since continued in these wonderful and pleasant dimensions." The same quaint writer speaks of Adam not only as a miner, but also as a refiner, &c., and nothing, he adds, shows wisdom more than the getting of gold by proper courses. The allusions made by some of the early writers to the getting of gold, and the minute directions which they give for the washing of gold found on the surface, warrant a belief that that precious metal was formerly prevalent on the surface, and it is by no means unlikely that its greater abundance in ancient than in modern times was one of the attractions which led to the peopling of the island by strangers, and that Britain was in ancient times to Rome and other nations what California and Australia are in our day. Certain it is that gold and silver have from early times been specially reserved by the Crown, and some remains of this are still apparent in the state of the law relating to treasures of these metals found under the surface of the earth.

From many circumstances, Alston Moor is best known as a lead-mining district from its having been open to public enterprise, and it forms a good type of the general condition of the lead-mining districts. Of its early history little is known. Its occupation by the Romans is attested by the

extent and perfect preservation of some of their large works, and the position of the mineral veins in it and the adjacent districts is such as to render it almost impossible that lead-veins were unworked. The formation of the great military road called the Maiden Way must have exposed to view the mineralogical characters of the rocks over which it passed, and the lead found in the Roman station at Whitley was most probably obtained from the immediate vicinity. Traces of ancient smelting-places exist, as may be inferred from the scoriæ yet to be found; but of any detailed operations or exact localities there is not, that we are aware of, any records. It is not until about six centuries ago that any light appears by which to judge of the state of the mining-districts, and even then, and for some centuries after, few and far between; and vague and undefined are the indications of lead-mining. The insecurity of property at that time, and more especially of Border property, may be noted; for even then the Kingdom of Scotland included Cumberland, although the mining rights were claimed by the English Crown. In the time of Henry IV. a lead-mine is mentioned as having been in Essex; and Sir John Pettus enumerates the following counties as producing lead-ore containing silver, namely, Devonshire, Gloucestershire, Worcestershire, Staffordshire, Leicestershire, Cheshire, Derbyshire, Lancashire, Cumberland, Northumberland, Yorkshire, Bishopric of Durham, Flintshire, Denbighshire, Shropshire, Carnarvonshire, Merioneth, Buckingham, Montgomery, Carmarthen, Brecknock, Monmouth, and Dorsetshires. From this it may be seen that for a long period lead-mining operations have been extensively spread over a great part of England and Wales, whilst in Scotland the chief works were almost confined to Leadhills, a place where gold was formerly obtained in some abundance. More accurate records would probably throw further light on the question whether in mining districts in southern parts of the island gold was or was not among the early inducements to search for hid treasures.

In Sir John Pettus's definition of poor mines and rich mines, or "mines royal," he states that "where the ore digged from any mine doth not yield according to the rules of art so much gold or silver as that the value thereof doth exceed the cost of refining, and loss of the baser metal wherein it is contained, or from whence it is extracted, then it is called poor ore or a poor mine. On the contrary, where the ore digged from any mine doth yield according to the rules of art so much gold or silver as that the value thereof exceeds the charges of refining and loss of the baser metal in which it is retained and from which it is extracted, then it is called rich ore or a 'mine royal,' and it is appertaining to the king by his prerogative." In this we have the definition of the limits within which it appears the mines of Alston were included as Mines Royal, and the importance of which is prominently marked in the several charities which the Kings of England in several successive reigns conferred by virtue of that prerogative. Sir John Pettus states that the mines in Devonshire, Somersetshire, and Cornwall were wrought by the Romans, who in the period of 300 or 400 years that they occupied the mining districts of the North of England doubtless exercised their knowledge of the ore, and Cæsar expressly mentions that one reason of his invading the Britons was because they assisted the Gauls with "the treasures with which their country did abound." It appears moreover that in those times, and long after, the practice was to condemn to the mines those who had committed any heinous offence against the laws of the land. In the beginning of the fourteenth century (1304) mention is made of indemnities granted to miners in Cornwall,

and liberty to turn watercourses for their works at pleasure. Thirty years later certain mines of lead mixed with gold and lead ore are mentioned in Shropshire. "A concealed mine of gold" is referred to (1401) in a letter of mandamus, and in 1426 Henry VI. granted to John, Duke of Bedford, "All mines of gold and silver within his kingdom of England for 10 years, paying the tenth part to the Holy Church, to the king the fifteenth, and to the lord of the soil the twentieth part." In 1438 the same king granted to John Sellers all mines of gold and silver in Devon and Cornwall, and all mines of lead holding silver and gold, to hold (from the expiration of 12 years formerly granted to the Duke of Bedford) for 20 years, paying the fifteenth part of pure gold and pure silver. In 1451 the same king made his chaplain, John Boltwright, comptroller of all his mines of gold and silver, copper, lead, &c., within the counties of Devon and Cornwall, and in the following year the same Boltwright is mentioned as "Provost and Governor of all his mines," and a grant was made to him of all mines of copper, tin, and lead, in Devon and Cornwall, to hold during his good behaviour, paying the tenth part of pure gold and silver, copper, tin, and lead, with power to let and set for 12 years, paying to the king the tenth bowl of ore, &c., holding gold or silver, and to dig without interruption, &c.

These notices, some of them referring to mines generally, and others only as contained in certain counties, are curious as showing the manner of the Crown's disposal of them. The constant mention of gold and silver is quite different to any mining conditions of modern times, and the limited periods of 10 or 12 or 20 years would seem to imply that no large works were contemplated—the continued security for a long period under which alone extensive and deep mines can now be worked not being required in virgin mines, when the readiness of the implements and machinery were adapted only for operations of an inconsiderable depth. In 1468, Edward IV. granted Richard, Earl of Warwick, John, Earl of Northumberland, and others, all mines of gold and silver, &c., on the north side of Trent, within England, and all mines of lead holding gold or silver in the same parts for 40 years, paying to the king the twelfth part of pure gold and silver, and to the lord of the soil a sixteenth part, with liberty to dig, except under houses and castles, without license. In 1475 the same king granted to Richard, Duke of Gloucester, Henry, Earl of Northumberland, and others, the mines of Blanchland called Shildon, in the county of Northumberland, and the mine of Alston Moor called Fletchers; the mines of Keswick, in Cumberland, and the copper-mine near Richmond, to hold the same for 15 years, paying to the king the eighth part, to the lord of the soil the ninth part, and to the curate of the place a tenth part as they arise. In 1478 the same king granted, on surrender of the former grants, to William Goderswick and Doderick Waverswick, all mines of gold, silver, copper, and lead in Northumberland and Westmoreland, to hold the same for 10 years, paying to the king a fifteenth part, and to the lord of the soil, and to the curate, as they can agree. In 1486, Henry VII., by his letters patent, dated February 27th, made Jasper, Duke of Bedford, and other Earls, Lords, and Knights, commissioners and governors (a designation retained until very lately in the direction of the estates of Greenwich Hospital) of all his mines of gold, silver, tin, lead, and copper in England and Wales, to answer the profits to the king, and made Sir William Taylor comptroller to hold the same for twenty years, with liberties of court and other privileges, paying to the king the fifteenth part of pure gold and silver, and to the lord of the soil the eleventh part as it

grows. For a period of about 50 years following the appointment of this commissioner in the reign of Henry VII., little of moment appears to have been done; and in the third year of the reign of Queen Elizabeth a society was appointed, entitled the Society for the Mines Royal, to whom a grant of gold, silver, and copper was given within the counties of York, Lancaster, Cumberland, Westmoreland, Cornwall, Devon, Gloucester, and Worcester, as also in Wales, with liberty to grant and assign parts and portions. The various laws and regulations of this and similar societies do not throw any light on the local details of mining, and the general rate of duties and conditions of the North of England lead-mines in the above periods can only be inferred from the probability of their having been included in some of the grants already recited.

In other lead-mine districts we find more minute details of local customs; such, for example, are the laws of the lead-mines of Derbyshire, and Mendip, in Somersetshire; but we find no trace of any of these peculiar customs having prevailed in Alston or the adjacent districts. One of the Derbyshire customs or regulations is curious enough:—"If any blood be shed upon the mine, the author shall pay 5*s*. 4*d*. the same day, or else shall double the same every day till it comes to 100*s*." 5*s*. 4*d*. was also the apparently moderate penalty in case of underground trespass. The laws and customs are described as being those of the mine used in the highest peak, and in all other places through England and Wales. The miners sued that the king "would confirm them by charter, under his great seal, by way of charity, and for his profit, forasmuch as the aforesaid miners be at all times in peril of their death, and that they have nothing in certain but that which God of his grace will send them." The information to be thus gleaned is scanty enough, and admits not of being woven into a connected narrative, yet it indicates the scale of payment to the several parties concerned, the shortness of the term for which grants were made, the absolute rights of the Crown, and the participation in a portion of the revenues by the Church. The mines of Alderston, or Alston, had royal protection granted in 1233, again in 1236, and again in 1237; in 1282 the manor of Alderston was granted by Edward I. to hold in fee of that King of Scotland, reserving to himself and to the miners various privileges, especially such as belonged to the Franchise of Tindale, within which Alston was then comprised. The details of grants and charters more immediately relating to Alston appear to correspond in general terms with those more general grants which we have specified as elucidating the early progress of mining in this kingdom generally. In 1333, several of the privileges above alluded to were confirmed to Robert, son of Nicholas de Veleripont, and in the following year some further liberties were confirmed, from which it appears that Alston at that period had not only mines, but a mint. These and some other details are contained in a brief account of the mining districts which one of the writers drew up more than 30 years ago, when residing in Alston Moor. The ancient names of Park and Forests which occur in these northern mining districts, as applied to extensive tracts of land which are now treeless, are worthy of mention, as they indicate in a striking manner the abundance of forest timber which once adorned the now nearly treeless districts under consideration. In 1290, Patric of the Gilt and 26 other miners were impleaded by Henry de Whitby, and Joan, his wife, for cutting down their trees at Alderston, by force and arms, and carrying them away to the value of £40. The miners claimed that they held the mine of the king, and were privileged to cut wood. The context sufficiently indicated that there had in

former times existed vast quantities of wood, that it was extensively used for the mines, and that the country was thus rendered bare and treeless, in which state only too much of it yet remains.

Another intimation contained in these ancient records leads to the supposition that mining cases were at one time subject to the decision of juries of miners similar to those which existed in other parts of the kingdom, and the proceedings of such juries one of the writers had occasion to investigate more closely in connexion with the Forest of Dean. Alston Moor afterwards became the property of the Hyltons, of Hylton Castle, in the county of Durham, and a lease was granted in 1611 for 999 years by Henry Hylton, subject to the payment of certain rents which amounted to £64. In 1629 the manor was sold to Sir Edward Ratcliffe for £2500, and it remained the property of that family till the confiscation of the estates of James, Earl of Derwentwater, in 1716. It was granted by the Crown in 1734 to the Royal Hospital for Seamen at Greenwich, and has ever since remained in the possession of the Commissioners in trust for that institution. Adjoining estates have subsequently been purchased, and added to the original tracts of land so given. It would be a work of some labour to extend these notices to the details of property and succession in the several other districts. The only practical result would be to discover a period when general and undefined Royal rights were gradually brought into narrow compass by increasing population, and when mining was doubtless encouraged by liberal immunities granted to miners. It would be difficult to pursue in any minuteness the gradual advance of improvement and distinct rights of property over clearly defined districts. The royalties of Allendale passed into possession of the Fenwicks of Wallington, of the Blacketts, and eventually of the family of the present possessor, Wentworth Blackett Beaumont, Esq., M.P. The Weardale mines are held under lease by the same owner from the Ecclesiastical Commissioners. The mines in Teesdale belong to various lords, of whom the Duke of Cleveland is the chief; and at and near Blanchland, in the valley of the Derwent, the royalties belong to H. Silvertop, Esq., and other proprietors. It is, however, interesting to endeavour to mark the periods at which the former vague and uncertain methods of mining in these lead districts were replaced by more exact ones, and it is apprehended that such a period of change may be distinctly traced in the supervision of that great engineer, Mr. Smeaton, who was for a time an agent of Greenwich Hospital in this district. It is certain that one great work which he projected and commenced at Alston, in 1775, gave a new stimulus to mining. This was the Nent Force Level, a work of great magnitude, of vigorous conception, well adapted to the then existing state of information, and to the imperfect state of engines where great power was required. In the present day an equal amount of exploration and drainage may be pursued by the use of hydraulic engines wholly worked by water. About the same period the progress of mining in Allendale owed much to the ingenuity of Mr. Wm. Westgarth, who first introduced water-pressure engines. The generous interest taken by Smeaton in the promotion of so useful a discovery may be seen by the communications of that great engineer to the Society of Arts. The minute details of the construction of Mr. Westgarth's engine may be seen in the early volumes of the Transactions of that society. "The old man" is the local phrase by which ancient mining operations in these districts are described. The greater or less abundance of produce of lead was scarcely matter of public interest, nor were the fluctuations of price such as would have been felt in the case of coal. Carried on in remote

districts, which, until half a century ago, were in many places almost inaccessible except on ponies, it is not surprising that few details of local history of an authentic and detailed character exist, or that we have only meagre traces of a secluded district, and of a people shut out in a great measure by their occupation even from the few dwellers on the surface of their own remote dales.

The earliest method of working lead-mines appears to have been by shaft, by following the surface-indications of ore downwards. The driving of levels for drainage in Dean Forest was of later orign, and probably so in the other mining districts of the kingdom. The work was drawn to the surface in kibbles, or small tubs, and some of the smaller pits on the basset of inferior beds of coal yet present what probably was the appearance of a respectable mine in the infancy of such operations. The general use of levels or galleries large enough to admit of horses travelling in them is said to have been introduced into the lead-mining districts by Sir Walter Calverly Blackett, about 120 years ago, but the example was not, as we believe, followed for many years by other mine-owners. Cast-iron rails, instead of wood, were first used in Nent Force Level. Tin pipes were first used for ventilation by Low, Carlisle, and Co., at Tyne Bottom Mine. Mr. Stagg introduced iron pipes at Rampgill, and Mr. Dickinson first used lead pipes for the purpose of ventilation in the Nent Force Level. Any of these materials were an improvement on the wooden boxes, which rapidly decayed, and so rendered the air impure, and which moreover could with difficulty be kept water-tight.

The quantity of lead ore raised in this Northern district and smelted in the different mills, in 1861, according to Hunt's 'Mineral Statistics,' was as follows:—

	Lead Ore. tons.	Lead. tons.	Silver. oz.
Durham and Northumberland	19,536	15,252	78,265
Cumberland	6,324	4,614	37,115
Westmoreland	2,392	1,576	21,214
Yorkshire	8,801	6,203	3,650
	37,053	27,645	140,244

Lead Ore, Lead, and Silver the produce of Cumberland for 10 *years ended* 1862.

Year.	Lead Ore. tons. cwt.	Lead. tons. cwt.	Silver. oz.
1852	8,410 17	5,877 15	52,893
1853	8,343 19	5,619 9	50,000
1854	9,890 18	6,662 16	42,020
1855	9,627 13	6,929 17	62,879
1856	7,311 8	5,321 1	51,931
1857	6,450 0	4,711 8	43,460
1858	7,235 13	5,207 14	43,721
1859	7,180 9	5,250 14	39,406
1860	7,041 10	5,130 7	32,806
1861	6,324 9	4,614 13	37,115
1862	7,173 13	5,241 10	41,911

Lead Ore, Lead, and Silver the produce of Durham and Northumberland for the 10 *years ended* 1862.

1852	21,594 3	15,978 11	191,736*
1853	19,287 16	15,041 4	140,000*
1854	22,329 15	16,669 18	78,577
1855	22,107 18	16,309 19	75,435
1856	24,125 7	17,674 11	79,924

* The Westmoreland silver is included in these quantities.

Year.	Lead Ore. tons. cwt.	Lead. tons. cwt.	Silver. oz.
1857	21,580 1	17,073 14	74,091
1858	19,999 2	16,776 7	78,238
1859	19,571 0	14,568 0	74,222
1860	20,200 12	15,186 0	84,254
1861	19,536 15	15,252 17	78,265
1862	21,177 18	16,454 0	82,854

Produce of Lead in the years 1845 *to* 1862, *inclusive, in the counties of Cumberland, Durham, and Northumberland.*

Cumberland. Year.	tons.	cwt.	Durham and Northumberland. Year.	tons.	cwt.
1845	5,861	0	1845	10,248	0
1846	5,556	0	1846	10,284	0
1847	5,702	0	1847	12,245	0
1848	5,684	0	1848	13,178	0
1849	6,327	7	1849	14,066	6
1850	6,850	4	1850	15,840	3
1851	6,333	2	1851	15,488	12
1852	5,877	15	1852	15,978	11
1853	5,619	9	1853	15,041	5
1854	6,662	6	1854	16,684	4
1855	6,929	17	1855	16,309	19
1856	5,321	1	1856	17,674	11
1857	4,706	1	1857	16,973	16
1858	5,168	2	1858	16,816	2
1859	5,250	14	1859	14,883	1
1860	5,119	4	1860	15,208	2
1861	4,581	8	1861	15,286	6
1862	6,241	10	1862	16,454	0

In concluding this part of the subject, one prominent feature may be mentioned, namely, the work called the Blackett Level, commenced by W. B. Beaumont, Esq., M.P., in East Allendale. The shafts on this work were commenced in 1855, and the Adit Level, near Allendale Town, was begun in 1859. The entire length, when completed, will be nearly seven miles. At three of the shafts, and also at the Allenheads mines, are extensive adaptations of the improved hydraulic engines invented by Sir William Armstrong, and particularly described by him at the meeting in Newcastle of the Mechanical Engineers.

Smelting Processes.—Various important improvements have been introduced into the treatment of lead ores, among which we may mention the substitution of the Spanish Economico furnace for the slag hearth, by means of which a better produce of lead is obtained from the refuse products of the mills. This Spanish furnace is a miniature blast-furnace, covered at the top, from which a flue conveys the fumes to the condensing chambers or chimney.

Another improvement, introduced since 1839, is the celebrated desilverizing process of the late Mr. H. L. Pattinson, by which large quantities of both lead and silver have been saved. This process is so well known that we do not think it necessary to describe it on the present occasion, especially as it was fully explained in a previous Report to the British Association.

A third improvement is the conversion of hard into soft lead by the process of calcining introduced by Dr. Richardson, at Blaydon, in 1840. This process consists in exposing the hard lead in a melted state to a current of hot air, by which the antimony and other impurities are oxidized. The oxides float on the surface of the molten lead, and are skimmed off from time to time. This operation is continued until a sample of the lead drawn from the furnace is found to be soft and malleable. The late Mr. George

Burnett, jun., applied this process to the softening of Spanish lead, and employed a large metal pan, set inside the furnace, in which this hard lead is melted. This improvement has been the means of developing a most extensive trade between this country and Spain. The Spanish ores on the east coast of Spain are smelted with the fuel exported from this country, and the hard lead is brought here to be softened and refined. The following Table shows the gradual development of this trade :—

Imports of Lead into Newcastle-upon-Tyne.

Year.	tons.	Year.	tons.
1844	213	1854	6,534
1845	1,453	1855	3,723
1846	3,939	1856	3,391
1847	2,276	1857	4,877
1848	1,697	1858	4,871
1849	3,958	1859	9,069
1850	7,287	1860	9,373
1851	11,915	1861	12,284
1852	7,317	1862	12,459
1853	7,421		

This hard lead contains, on an average, about 50 oz. of silver per ton, so that the quantity of silver extracted on the Tyne is now upwards of 600,000 oz. per annum.

The total imports of lead into this country in 1861 were 23,109 tons, of which a considerable portion was from Linares, in Spain. This lead contains very little silver, and the average contents may be taken at 40 oz. per ton on the total imports. The total production of British mines in 1861 was—lead, 65,643 tons, and silver, 563,731 oz. Hence the imports and productions of these metals in this district amount to 45 per cent of the lead, and upwards of 50 per cent. of the silver of the whole trade of Great Britain.

Several improvements have also been introduced for the condensation of the fumes evolved in the various smelting and refining operations to which lead is submitted. The first in point of time is the horizontal flue or chimney, which was first used by the late Messrs. Crawhall and Johnstone, in Mr. Beaumont's extensive mills. The flues are built of masonry, eight feet in height and six feet wide. The aggregate length of the flues in the mills belonging to Mr. Beaumont is nine miles. Another plan, adopted in the mills of the London Lead Company, is the invention of the late Mr. Stagg. It consists in drawing the entire gaseous products of the furnace through water, by means of powerful pumping machinery. The lead fume is completely condensed, and easily separated from the water, where it is allowed to collect and remain at rest in suitable tanks. Mr. Stokoe's plan has been introduced at Langley and other smelting establishments. In this plan, the lead fumes are driven by a fan-blast through a series of ascending and descending columns, partially filled with brushwood, on pebble stones, down which a stream of water falls to condense the lead-fumes. The water collects in tanks at the bottom of the columns, and the fumes are allowed to subside.

We have heard that a small quantity of pure ore is reduced in crucibles by means of iron, similar to the process employed in treating antimony ore, with the object of obtaining a lead of great purity, for the production of red lead to be used in the manufacture of flint-glass.

Manufacturing Processes.—This locality has long been celebrated for its manufactured leads. The first establishment is said to have been commenced about a century ago, and those at the Ouseburn and Gallowgate were erected about the year 1799.

White Lead.—The greater portion of this article is manufactured by the old Dutch process, and we have no important improvement to notice. The levigation is conducted with improved machinery, and the yield of white lead has increased, with a greater attention to the conditions necessary to ensure a more perfect corrosion of the lead.

Mr. Pattinson's beautiful process for making oxychloride of lead is worked at Washington. This plan consists of decomposing lead ore by hydrochloric acid, when a pure chloride of lead is easily obtained. This substance is then partially decomposed by an earthy base, leaving an amorphous oxychloride of lead behind, which is used in the same way as ceruse or white lead.

Red Lead, &c.—The manufacture of orange and red lead, litharge, is still conducted in the same way, but in every case with improved and more effective machinery.

Sheet Lead and Lead Pipe.—The manufacture of these articles has largely increased, and much more powerful machinery has been introduced, by which the sheet lead is now made of a greater width than formerly. Messrs. Walker, Parker and Co. manufacture a tinned lead pipe, which admits of its use in many cases where a leaden surface would be objectionable.

Shot have been long manufactured here. The Shot Tower is a striking object, towards the west of the town, on the banks of the river. It was erected at the close of the last century, to carry out the patent process of Mr. Watts. A short time afterwards the late Mr. Burnett, with great shrewdness, substituted an old pit-shaft at Wylam for the purpose of casting shot. The manufacture of shot embraces several interesting processes; but as no recent improvement has been introduced, we must limit our remarks to the above brief historical notice of this branch of manufactured leads.

Statistics.—From the information which has been kindly furnished by Messrs. Forster, Leithart, and Parker, we are enabled to give the following details of the quantities of these articles made in this district.

	tons.		tons.
White Lead and Paint	7,500	Lead Pipes	1,500
Red Lead	4,500	Shot	750
Litharge	800		
Sheet Lead	4,500		19,559

Copper.

The smelting of ores of copper in this locality is of recent origin, and is due to the importation of cupreous pyrites, which are used by the alkali-makers for the manufacture of sulphuric acid. The chief supply is obtained from Spain; but the pyrites which arrive from Cornwall, Ireland, and Sweden also contain copper. The following analyses, by Messrs. Browell, Clapham, and Marreco, exhibit the composition of the sulphur ores:—

	Cornwall.	Ireland.	Spain.	Sweden.
Sulphur	34·345	47·41	43·52	38·05
Iron	32·200	41·78	40·20	42·80
Copper	·800	1·93	3·12	1·50
Lead	·400	—	2·11	—
Zinc	1·325	2·00	0·32	—
Arsenic	0·910	2·11	1·10	—
Silica	29·000	3·93	8·00	12·16
Insoluble matter	—	1·43	—	—
Moisture	—	1·43	1·54	—
Oxygen and loss	—	—	—	5·49
	98·980	100·59	99·91	100·00

These ores are usually burnt in the ordinary kilns for making sulphuric acid; but one manufacturer on the Tyne employs Longmaid's process for making sulphate of soda, in which case the copper is obtained as sulphate. The burnt ores are afterwards run down to regulus, either alone or mixed with copper ores and slags, which are imported from the Continent. Some of the manufacturers only carry their operations up to the point of making a regulus with 50 per cent. of copper, while others produce tile-copper. The *lit de fusion* varies with the character of the ore, and the following mixtures are used for the purpose :—

	cwt.	cwt.	cwt.
Raw ore	1	0	0
Burnt ore	20	21	7
Siliceous ore	0	0	18
Copper slags	8	4	0
Sand	3	3	0
Tank waste	0	0	4
Fluor spar	0	0	1½
Coal	0	2	0

Messrs. Mease and Co. dissolve out the copper with sulphuric acid, and precipitate this metal by means of iron.

The quantity of copper ore raised in the northern counties is very small, being only 131 tons per annum, and the imports are given in the following Table :—

Imports of Copper Ore and Slags.

	1857.	1858.	1859.	1860.	1861.
France	739	80	0	233	74
Norway	558	94	8	9	14
Denmark	1	0	0	0	2
South America	0	111	15	0	0
Belgium	0	0	2	0	0
Germany	0	0	7	9	1
Turkey	0	0	1	0	0

The present annual production of copper on the Tyne is about 700 tons.

Zinc.

The ores of this metal are not very abundant in this district; but blende and calamine are found in the neighbourhood of Alston. Ores of zinc are imported from the Isle of Man and Ireland, through the ports on the west coast, and from the Rhine and Sweden to the Tyne. Well-arranged smelting-works have been erected by Mr. Attwood, who employs a modification of the Belgian process for the reduction of the ores. The annual produce of spelter varies from 750 to 800 tons.

Mr. Hunt gives the following returns of the production of these ores in this locality :—Alston, blende, 366 tons; calamine, 135 tons; sundry mines, 95 tons: total, 596 tons.

Antimony.

The ores of this metal are all imported and smelted by one firm, who produce annually about 270 tons. The process of reduction is that generally employed, and we have heard that the sulphur matt is treated with sulphuric acid to obtain green copperas.

Nickel and Cobalt.

The works where these metals were extracted from their ores are not at present in operation.

On the Magnesian Limestone of Durham.

By JOHN DAGLISH, *F.G.S., and* G. B. FORSTER, *M.A.*

COVERING as it does so considerable a portion of the Northern Coal-field, the Magnesian Limestone must always afford a most interesting study to those engaged in the mining operations of this district. This arises from its important bearing not only on geological, but also on physical conditions; the former have long been a subject of general interest, and as regards the latter, one of the most marked features is the large quantity of water met with in the shafts which have been sunk through it for the purpose of winning the coal below. It was more especially to this feature that this paper was, in the first instance, proposed to be directed; but in the preparation of the required maps and sections, it was found that allusion to other debateable ground could not be avoided.

This deposit has, at various times, occupied the attention of some of our ablest geologists, and has been carefully investigated by them, so far as it can be seen in its sections open to the day; but the writers, in the pursuit of their professional duties, having had frequently brought before them sections of the entire deposit in the numerous coal-shafts which have passed through it, and having obtained the true inclination of the Coal-measures underlying a large tract of the Limestone in the workings of the various coal-mines, have had suggested to them conclusions somewhat at variance with the opinions expressed by recent writers, and which they deem of sufficient interest to bring before this Association.

In all the sinkings through the Magnesian limestone, feeders of water, more or less considerable, are met with at a certain distance from the surface, derived not so much by percolation through the mass of the rock—for this can obtain to a small extent only—but collected in and coming off the numerous gullets and fissures which everywhere intersect and divide the mass of strata. If the shaft be not drained by pumping, or otherwise, the water from these feeders rises to a point which remains, save in exceptional cases, constant. A line drawn between these various ascertained points gives the line of saturation, indicated by dotted lines, on the sections exhibited; and it will be observed that, although this line commences at the sea-level, it neither continues on this plane nor follows the line of stratification, nor yet all the undulations of the surface, but rises for the most part uniformly with it as it passes inland. At Seaton Pit, near Seaham, it is 226 feet from the surface, and at Eppleton, three miles directly west of Seaton, it is the same; and as the surface-level of the latter is 180 feet above that of the former, it follows that the line of saturation rises in this direction at the rate of 60 feet per mile.

It was mentioned previously that under certain circumstances there is a slight variation in the level of the line of saturation; this occurs sometimes near the outcrop of the Limestone, when after a long succession of wet weather the level is raised a few feet; and, again, in some cases where gullets are exposed on the surface, down which large quantities of water from flooded brooks, &c., find their way, and hence in any shaft communicating with these gullets the water rises rapidly and considerably.

Immediately underlying the Limestone is a bed of sandstone of very variable thickness, which when exposed to the action of the atmosphere disintegrates rapidly, and has hence acquired its local name of "friable Yellow sandstone." It is in sinking through this bed of rapidly decomposing sandstone that such great engineering difficulties have been encountered, owing to the enormous

quantity of water which in some cases is met with, more especially if the bed be thick, and much below the level of saturation. A very full account of the sinking of the Murton Winning is given by Mr. Potter in vol. v. of the 'Transactions' of this Institute. In this case nearly 10,000 gallons of water per minute were pumped out of this bed by engines exceeding in the aggregate 1500 horse-power. The circumstances which favour the remarkable accumulation of water in the Limestone, and the rapidity with which it is drained off into pits sunk through it, are due to several causes, some of which are peculiar to this formation, and perhaps to this district. They are:—

1st. The arrangement of the beds of stratification.

2nd. The contour of the country.

3rd. The permeability of this formation to water.

On examining the locality, it will be observed that the beds of stratification dip towards the sea at an angle somewhat more inclined than the surface of the ground, so that on this line of section the Magnesian limestone crops out with a bold escarpment about four miles inland from the sea, forming one of the most pleasing features in the landscape of the south-eastern portion of Durham. An observer standing on the escarpment and looking inland would have an extended view over the wide expanse of flat country which, owing to the softer character of the rocks of the Coal-measures, lies at its base, and frequently running up into the Limestone in deep bays or fiords, gives it the character of an ancient rugged coast-line. Seaward an entirely different aspect is presented—a series of undulating hills, intersected with many deeply-cut, picturesque, and beautiful ravines, which being low and sheltered are well wooded and clothed with luxuriant foliage. The boldness of the escarpment is no doubt to a certain extent due to the soft nature of the "Yellow sandstone" lying immediately at its base. This sandstone sometimes reaches a thickness of 50 feet, and extends over the flat base to a considerable extent beyond the Limestone, and being thoroughly pervious to water, forms a natural absorbent for all the drainage of the district around, which is further increased by the numerous before-mentioned bays running into the Limestone. In addition to this, over the country extending from the outcrop of the Limestone to the sea, the large fissures already spoken of as intersecting in all directions the Limestone, form so many channels of communication between the surface and the bed of "Yellow sandstone," down which the surface-drainage, and even in some instances small streams pass freely. It cannot, therefore, be wondered at that when this formation is pierced by any shaft below the level of saturation large volumes of water should be encountered; and although this may for the time increase the engineering difficulties and frequently add much to the cost of winning coal through the Limestone, it has at the same time its brighter points of view, affording as it does an inexhaustible supply of pure and agreeable water to the inhabitants residing on its surface. The large towns of Sunderland and South Shields are entirely supplied by water pumped at extensive works at Humbledon, Fulwell, and Cleadon Hills. The town of Seaham Harbour is also similarly supplied. The water is hard for domestic purposes, but delightfully clear and refreshing.

There is another point connected with this branch of our subject which affords much scope for conjecture as to its cause, and offers a large field for further research. In all the deep winnings made near the sea-coast, the water met with below a certain depth is saline, but not to a uniform degree, gradually becoming more so as the depth increases, until it attains the same specific gravity as the water of the North Sea. It is difficult to obtain the

law regulating the increase of density, as a great number of experiments would require to be made extending over a considerable area, and great care that the waters tested are not locally contaminated by contact with decomposing rocks. The results of the testing of a great many samples obtained at various depths over the Hetton, South Hetton, Murton, and Seaham estates, extending over an area of about thirty square miles, were described.

From this it would seem that the line of uniform saltness, so far as the above researches go, by no means follows either a line of uniform depth, or that of stratification, and does not depend on the contour of the country or the line of saturation.

The water of the greatest density was obtained from the roof of the Hutton seam, at Seaton Colliery, at a depth of 1500 feet from the surface, or 1260 feet below the level of the sea. This density was 1·026, being nearly that of sea-water.

In other parts of this coal-field, however, as at Walker, Framwellgate, Butterby, Lambton, Birtley, and St. Lawrence, saline springs of an entirely different character are met with at various depths (in the case of Framwellgate and Butterby coming to the surface), and at some of these places the springs have been used as brine-springs for the preparation of ordinary salt.

Various opinions are held by geologists as to the precise structure of the Permian series of this district, and their relationship to the subjacent rocks. Perhaps, with little exception, all the older geologists, and those not residing in this neighbourhood, consider the Permian series of this district to lie unconformably on the Coal-measures, and that the Yellow sandstone and Red sandstone beds form a part of the Permian series, and are conformable to the overlying Magnesian limestone.

On the other hand, local geologists, whose opinions, from their opportunity of examination and from the attention which they have bestowed on this series of rocks, are well worthy of every consideration, are of opinion that the Yellow sandstone and Red sandstone beds form part of, and are conformable to the Coal-measures, and do not belong to the Permian strata. This view, however, does not seem to be borne out by well-ascertained facts; questions of conformability, in all cases connected with the Yellow sandstone, must be doubtfully entertained, as this rock lies more in hills than in beds; and the question of its conformability to the Limestone must be settled by examination over an extended area, as, indeed, is essential in order correctly to ascertain all questions of conformability. It may be observed, that whilst at Monkwearmouth Pit the Coal-measure strata intervening between the Magnesian limestone and the Hutton seam are 1500 feet, at Seaham they are 1100 feet, and at Castle Eden only 400 feet. So that at Castle Eden 1100 feet of Coal-measure strata have been denuded, and yet the Yellow-sandstone underlies the Limestone at each place.

With respect to the "Red beds," it would seem to the writers that if they can be proved to be independent beds, they must also be conformable to the Limestone, resting with it unconformably on the edges of the Coal strata; but for several reasons they venture to express an opinion that they do not exist at all as independent beds, but are merely the reddened edges of the Coal-measure rocks themselves.

The following are the reasons which have led the writers to entertain this view:—

1st. Beds of "Red rocks" are frequently met with below the coal-seams in sinking shafts, as is shown at Monkwearmouth, Ryhope, Seaton and Castle

Eden, Murton and Eppleton, and Elemore Pits, and they can be seen cropping out below a coal-seam in the cliffs a little to the north of Cullercoats Haven.

2nd. The fossil remains in the "Red beds" are identical with those of the Coal-measures, as shown by Mr. Howse in his paper on the Permian Fossils (Tyneside Naturalists' Field Club Transactions, vol. iii. p. 235). And yet, if independent beds, they are not "the upper beds of the Coal-measures," because in all sinkings, &c., they are found to underlie the Limestone and Yellow sandstone even when, as previously mentioned, in treating of the unconformability of this rock to the subjacent coal-formation, an enormous thickness of Coal-measure beds has been denuded off. Further, wherever any coal-seam has been worked, as at Kelloe, Cornforth, &c., nearly to its outcrop under the Limestone, the stone forming the roof becomes red—clearly proving either that these red measures are simply the reddened edges of the crop of the Coal-measures, or that they belong to the Permian series, resting unconformably with them on the Coal series.

3rd. This red appearance of rocks has been observed in other parts of the Coal-measures where its origin could be distinctly traced.

1st. The shales forming the roof of coal-seams are frequently found discoloured and reddened in the galleries of the mine where they have been exposed to the action of the atmosphere for some time.

2nd. This character has been found strongly marked in the rock surrounding upcast shafts when the action of decomposition has been accelerated by increased temperature and probably by percolation of water.

3rd. In one special instance, viz. in the recent sinking of the Camboise Pit, which is situated close to the sea, and at the outset passes through 7 feet of recently-blown sand. The bottom of this sand was found to be quite reddened, and in appearance strongly resembled the red rocks below the "Yellow sandstone," which latter, from its lying in hills, from its incoherent character and false bedding, was probably originally blown sand.

It is not difficult to understand that the Coal-measure rocks, by lengthened exposure to the action of the atmosphere, as must have been the case prior to the deposition of the Limestone, would become reddened to the extent now witnessed, when it is considered that they all contain so large a quantity of iron, and that, under circumstances at all favourable, they readily take on them this character.

The writers propose now to treat shortly of the general stratigraphical character of the Magnesian limestone of this district.

Hitherto it has been usual for geologists to divide this formation into four distinct beds, or groups of beds; and these subdivisions have been compared to other series of beds extensively developed in other parts of Europe.

These groups of Magnesian limestone rocks have been named by the following authors thus:—

In 1850 Professor King published the following arrangement of the Magnesian limestone:—

In England.	In Germany.
1. Crystalline.	Stinkstein.
Brecciated. / Pseudo-brecciated.	Rauchwacke.
Fossiliferous.	Dolomit.
Compact.	Zechstein.

In 1857 Mr. Howse proposed the following division of the Magnesian limestone, which has been adopted by Mr. Kirkby, by Professor Geinitz, of Dresden, and also by Professor King more recently:—

	English Series. *Magnesian Limestone.*	German Equivalents. *Zechstein.*
1. Upper Group......	*a.* Upper yellow-limestone.	*a.* Plattendolomit, and
	b. Botryoidal do.	*b.* Kugelkalk, &c.
2. Middle Group	*c.* Cellular, and	*c.* Rauchwacke.
	d. Shell-limestone.	*d.* Dolomit, Asche, &c.
3. Lower Group	*e.* Compact limestone, and *f.* Conglomerate.	*e.* Zechstein.

Doubtless, any one examining these rocks, by commencing at their outcrop near South Shields, which is the usual starting-point, and going southward along the coast, would readily recognize these groups. The line of separation between the compact and cellular rocks is clearly distinct, as is also the first appearance of the botryoidal rocks, south of Marsden. But there are equally well-defined changes in the character of the rocks at other points along the coast (as at the point near the blast-furnace south of Seaham Harbour) which have not been made use of for grouping the Magnesian limestone into distinct series of beds; and there are also, south of Seaham, several other groups of shell rocks with distinct and variously-marked differences of lithological character. It is not at all to be wondered at that these points of strongly-marked difference of lithological character, and apparent non-conformability of deposition, should occur throughout such an extensive deposit as the Magnesian limestone. These occur constantly to a far greater extent throughout the Coal-measures, and yet it would be extremely hazardous to venture on any speculative subdivision of those rocks*; most probably all the variations of lithological structure, running through all the stages of friable, earthy, rubbly, starry, marly, crystalline, botryoidal, coralloidal, spheroidal, mammillated, brecciated and pseudo-brecciated, soft-laminated and hard-laminated, conglomerate, conglobate, concretionary, oolitic, and honeycomb, are simply due to the effects of local action at the time of deposition—rocks of the same stratigraphical position taking alternately any or all of the above lithological types.

On the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field. By Isaac Lowthian Bell, *Mayor of Newcastle.*

There is probably no district, where the manufacture of iron is carried on, which presents more features of interest, and embraces within its range greater variety, than that which is worked in connexion with the coal-field of Northumberland and Durham. Notwithstanding this, the iron metallurgy of the North, which it will be the province of this paper to explain, owes none of its importance to the existence of any of the ores of iron in those measures which belong more immediately to the coal-formation. In Scotland, Staffordshire, and South Wales, the shales of the coal-measures

* The roof of a seam of coal consists at one place of a hard sandstone, which, thinning out more or less abruptly, is replaced by soft shale, and at times the shale comes in as a wedge, without displacing the sandstone, and gradually increases to a thick bed. Even beds of coal themselves, commencing with a few inches, thicken to many feet, are separated by layers of shale into distinct seams, and again become one by the disappearance of the band of shale.

contain bands and nodules of ironstone in sufficient quantity to supply immense works, established in these localities, for smelting iron. The coal-field of the North of England, on the contrary, extensive and productive in mineral fuel as are its strata, is singularly deficient in those ores of iron which distinguish many other carboniferous districts. An explanation, then, of the prominent position occupied, as a seat of the iron-trade, by the locality under consideration, must be looked for in another direction, and a very brief mental survey of the geology of the adjoining country will furnish the necessary information. Starting from the coal-field itself, which, as containing the fuel required for smelting, may be considered as the keystone to the whole, we arrive within no great distance at strata which abundantly compensate for that poverty in ironstone already spoken of as inherent to our coal-measures themselves.

The district known as the Newcastle and Durham coal-field contains an area of something like 700 square miles, and in shape may be roughly considered as an isosceles triangle, having its apex coincident with the coast-line at Warkworth. As the sea principally forms its eastern barrier, our observations are necessarily almost exclusively confined to those formations bounding it on the west and south. In the former direction, *i. e.* towards the west, a narrow strip, having a width of four or five miles, of the millstone grit, rising up from under the coal-formation, separates this latter from an extensive tract of country, of which the mountain limestone is the prevailing rock. From the south-west corner of our coal-field, and separated from it by a great expansion of the millstone grit accompanied by mountain limestone, we pass over a thin wedge of the old red sandstone and enter upon the new red, to the west of which the carboniferous limestone again appears as a long, narrow, curve-shaped district, extending from Penrith to Whitehaven, and of importance in describing our subject. On the south, and skirting the coal-field on the south-east, we have the magnesian limestone some half-dozen miles in width. Beyond it, forming for some distance the valley of the Tees, is the new red sandstone, separating, by an interval of twenty miles, our collieries form those hills of lias in Yorkshire, the ore of which will form the greater portion of the subject of this paper.

We will now briefly allude to the position of the minerals which constituted the sources whence our furnaces in former times were supplied, adding a few remarks on their practical application, and then consider those means which at the present day furnish our greatly extended ironworks with that immense quantity of raw materials which their increased capacity demands.

We may pass over without further notice at the present moment both the immense beds of coal, of the purest kind, in this northern coal-field, and the inexhaustible supplies of lime furnished by the extensive tracts of mountain and magnesian limestone previously alluded to. We shall, therefore, at once proceed to name the different combinations in which ironstone is found in the various strata of the measures already referred to, reserving any further remarks when we come to speak of the composition and nature of the minerals generally.

Ironstone of the Coal-measures.—Many of the numerous beds of shale associated with the coal-formation in this neighbourhood contain, interspersed in their thickness, nodules of ironstone, but these have rarely been sufficiently abundant to lead to their being worked for smelting purposes.

Above the seam of coal known on the Wear as the High Main, and separated from it by a distance of 18 inches, is a continuous band of this ore. It is $4\frac{1}{2}$ inches thick, and was formerly wrought on Waldridge Fell for the

Whitehill Iron Works, and subsequently at Urpeth and its vicinity for the furnaces at Birtley. Another thinner band, only 2 inches in thickness, formed the roof of the Hutton Seam, near Birtley. From the fact that both these were extracted by simply bringing down the roof of the old coal-workings, it was expected to supply the furnaces there at a very cheap rate, and this might have been so had the quantity per acre been larger. As it was, the ironmasters had to seek far and wide for supplies, and, in consequence, the cost of stone was ruinously high. The present partners in the Birtley Works have kindly placed in the writer's hands their cost-book, and from it, after the furnaces had been in operation four or five years, the following results are taken :—

	Ironstone used per ton.			Cost on ton of iron.		
	cwts.	qrs.	lbs.	£	s.	d.
1835	65	0	19	2	18	$1\frac{1}{2}$
1836	67	1	5	1	17	$0\frac{1}{2}$
1837	71	0	27	2	7	$3\frac{1}{4}$
1838	67	0	17	2	2	$8\frac{3}{4}$

From their furnace-books this appears to have represented the calcined weight, and hence the yield of the raw stone must have been from 25 per cent., gradually falling to 22. At this time hot blast was in use at the Birtley Works, the system having been introduced there about 1831. Mr. George Clayton Atkinson, a partner of the Tyne Iron Company, has obligingly given the following as their consumption for the year 1812, using stone of a similar kind to that described above ; indeed, a considerable quantity was purchased from the owners of the Birtley Iron Works, previous to the erection of the establishment at that place. The quantity used was 8772 tons, which cost on an average 16*s.* 1*d.* per ton. During that year they produced 2547 tons 18 cwt. of iron, and, in addition to the above-mentioned ironstone, 284 tons of hematite were consumed. If the small quantity of this latter ore is assumed to give 50 per cent., the yield of the clay ironstone would be something above 27 per cent. The difference in the produce may have arisen from less perfect freedom from adhering shale in the Birtley furnace-workings—a supposition corroborated by the increased consumption there to the ton of iron in later years, when failing supplies would prevent proper "weathering" of the ironstone. In 1812, the ironstone per ton of iron cost the Tyne Iron Company £2 18*s.* 10*d.*

Near Wylam, according to Mr. Benjamin Thompson, who erected the works at that place, a mine was opened in 1836, out of which, from a section of 4 feet, four bands, measuring together $10\frac{1}{2}$ inches, were obtained. This cost, it was stated, 7*s.* 6*d.* per ton of $22\frac{1}{2}$ cwt., and yielded 30 per cent. of iron. Another working supplied nodules having a percentage of 35 to 37, and costing 11*s.* 6*d.* per ton. The united produce, however, of both did not suffice to supply 150 tons weekly, and these mines were speedily abandoned when a less precarious mode of obtaining ironstone offered itself, although the cost of the latter would, at the period of its first introduction, have not been less than £2 on the ton of iron.

At Shotley Bridge, on the western edge of our coal-field, and consequently low down in the series, is a deposit of ironstone, which has been far more extensively worked than any other seams found in our coal-measures. According to a description by the late Mr. William Cargill, in a working having a section of about 7 feet in height, 12 to 15 inches of stone were obtained from six or seven bands. The ironstone from it cost 7*s.* to 8*s.* per ton. At a depth of $4\frac{1}{2}$ fathoms below it, and lying above 20 inches of coal, is a bed of shale about 3 feet thick, containing 6 or 7 inches of ironstone. The total

yield of both seams, contained in an acre of ground, Mr. Cargill estimated at 5324 tons. In later years, however, according to a detailed report communicated by Mr. Edward T. Boyd, the average produce of the first-mentioned seam, "The Ten Band," as it was called, at that time was 8 inches of ironstone in a working 5 feet 9 inches high, and in the other bed his section gives—

Good coal	1 ft. 6 in.		
Splint do.	0 7		
		2 ft. 1 in.	
Ironstone	0 4½		
Shale	3 6		
		3 10½	
		5 11½	

For a limited supply, the quantity of ironstone found in this neighbourhood might have sufficed; but an immense work having been erected upon it, comprising fourteen blast-furnaces, serious inroads were soon made on its resources. From information formerly received, it would not appear, whatever might be the richness of clean stone, that its yield, as delivered to the furnaces, exceeded 26 per cent. The cost on a ton of iron, for ironstone, at Shotley was 25*s.* to 30*s.*, which compelled the owners of this establishment to look to another district for their supplies, so that at the present time every pit on their royalties is laid in.

A small quantity of ironstone continues to be extracted from a landsale colliery at Hedley, which is smelted at Wylam, and, as the writer believes, some is still worked by the Weardale Iron Company near Tow Law. In a general sense, however, it may be assumed that ironstone of the coal-formation of the North of England forms no element at the present day in the consumption of the blast-furnaces of that district.

The Iron Ores of the Mountain Limestone.—Following the order of our description of the geology of the country, the deposits of ironstone connected with the mountain limestone next demand notice. In this series there occurs a bed of shale 30 feet in thickness, in the whole of which considerable quantities of nodules of ironstone are interspersed. The late Mr. Thomas J. Taylor, in evidence on the Border Counties' Railway Bill before a Parliamentary Committee in 1854, stated this shale bed to contain 9680 tons of ironstone to the acre, of which he assumed practically 6000 could be obtained. Its cost he stated to be 6*s.* 6*d.* to 7*s.* per ton, and its yield such as would require $3\frac{1}{4}$ tons of stone to produce one ton of iron, equal to 30·5 per cent. Mr. Benjamin Thompson, who worked this bed at Hareshaw, informs the writer that 8470 tons of ironstone per acre was its contents, and of this the lowest 6 feet contained two-sevenths of the whole. Allowing one-third for loss, he considered 5647 tons as the practical produce of an acre. Its yield he gives as 33 per cent., and its cost 9*s.* per ton of $22\frac{1}{2}$ cwt., equal to 8*s.* per ton of 20 cwt. At Ridsdale, from data possessed by the writer, the cost of ironstone for a ton of iron was 29*s.* 3*d.* This deposit has been somewhat extensively wrought at Hareshaw and Ridsdale, as well as attempted at other places. In all these localities, however, the workings have been discontinued.

At Chesterwood, about two miles from Haydon Bridge, there was opened out, some years ago, a seam of what in some measure resembled the famous "Black-band ironstone" of Scotland, containing, however, much more coal than the celebrated ore of this name. It varied, according to Mr. Bigland, who worked it, from 3 to 4 feet in thickness. The raw stone contained 20

to 25 per cent. of iron; but instead of 2 tons of raw mineral producing 1 ton of calcined, as in the case of Scotland, 3 tons were required at Chesterwood; so that the richness of the calcined stone was about the same, viz. 60 per cent. Mr. Bigland states that for several years they obtained 20,000 to 25,000 tons of the raw stone, until the bed was exhausted in that locality in 1855, after less than ten years' working. The deposit has been traced to other places, but in each case it is thin and poor in metal.

In Alston Moor many of the mineral veins traversing the mountain limestone contain a considerable quantity of a hydrated peroxide of iron, as well as amorphous carbonate of iron. A bed of the latter lying on the surface, but of very limited extent, was worked by the writer's firm at Nent Head, and smelted at Wylam. The iron produced from it, as well as from other carbonates and oxides from the same district, was of excellent quality; but unfortunately the supplies were too uncertain and too costly. The ore in the veins themselves at one time was tolerably pure carbonate, yielding perhaps 30 per cent. or more of iron; but it gradually passed into carbonate of lime, from which it was with difficulty distinguished. At the present day only a small quantity is worked at Alston. On the other hand, at Weardale the veins contain so much carbonate and oxide of iron that furnaces have been erected at Tow Law, by Messrs. Attwood and Baring, for their reduction.

The small district of mountain limestone spoken of as stretching from Penrith to Whitehaven contains very large quantities of most valuable red hematite, containing 60 per cent. and upwards of iron. It is sold at Whitehaven at about 10*s.* per ton. Its position is uncertain in a mining point of view, occurring in detached masses of varied thickness. This locality, as well as that near Ulverstone, of a similar character, is of importance in connexion with the northern coal-field, inasmuch as considerable quantities of the hematite ore are brought over to the east coast as a mixture with our own ironstone; while, to the furnaces smelting the produce of the Whitehaven mineral field, coke from our side is conveyed.

Iron Ores of the Lias Formation.—The Lias rocks of Yorkshire constitute by far the most important source from which the needful supplies for our furnaces are derived. The seams of ironstone belonging to this formation crop out on a considerable extent of the coast-line of the shale beds, which, in addition, contain large balls of the same ore. In rocks so liable to disintegration from atmospheric influence these have fallen away, and in consequence considerable quantities of ironstone, freed from the adhering shale, are to be found on the beach as rounded pebbles, and even as masses of rock. In modern times the ore so separated from its parent bed attracted the attention of those ironmasters who commenced smelting the ironstone of the coal-field. Mr. Joseph Cookson, in a very interesting document drawn up for the writer, mentions that for the Whitehill furnace, built in 1745, and abandoned before the end of last century, ironstone was gathered in Robin Hood's Bay, and conveyed by water to Picktree, on the Wear, near Chester-le-Street, and carted from that place to the works. Soon after the year 1800 the Tyne Iron Company obtained ironstone in a similar way from the beach between Scarborough and Saltburn; and, according to Bewicke, in his work on the Cleveland ironstone, that firm commenced, between the years 1815 and 1820, to tear up the stone from its bed at different parts of the coast. The exposed character of the Yorkshire shores and want of shelter rendered the conveyance of ironstone to the Newcastle furnaces a task of great difficulty and of some danger; and, therefore, it was not until the stratum furnishing

it was discovered inland on a line of railway, at that time recently opened, that any large quantity of this lias ironstone was consigned to the iron-masters of the Tyne. It is stated that the discovery of this bed is due to a Mr. Wilson, then a partner in the Tyne Iron Company's Works, who pointed out its position at Grosmont, about five miles from Whitby, in 1836. The seam, being $4\frac{1}{2}$ feet thick, was cheaply worked, sent down the railway, and shipped at all seasons for the Tyne, where it would at that time cost about 9*s.* per ton. It is probable that ultimately as much as 80,000 to 100,000 tons of it were annually smelted in the north-country furnaces.

Much surprise has been expressed at the time which elapsed between this discovery in 1836 and the period when the importance of the bed of ironstone became so immensely increased by the large quantity of ore extracted from mines opened in it since 1850. This is not so difficult of explanation as might at first appear. The Whitby ironstone, as it was then generally called, was known over a distance of coast not far short of ten miles; and its character to the west, five miles inland, had been also sufficiently explored. Over the whole of this area its yield of metal had been uniform, viz. about 25 per cent. No doubt the owners of the blast-furnaces which had been built on the Tyne for smelting local ores were too glad to obtain a cheaper stone elsewhere, particularly when hot blast increased the consumption of their furnaces, already indifferently supplied, and competition with Scotland ran down the price of iron. Whitby harbour, for these firms, was more convenient than the Tees, because vessels coming down in ballast more easily ran into the former than up the somewhat intricate navigation of the river, and there was no reason to suppose that a seam of ironstone which had so uniformly maintained a low percentage over fifteen miles of country should, in this respect, as well as in others, change so rapidly in the next dozen miles. That the introduction of the stone from Whitby did not confer any great advantage on the Tyne smelters is proved by the fact, that for fourteen years after its discovery only two furnaces, and those built under somewhat peculiar circumstances, were added to the five in blast previous to the importation of this ore. The fact was that, with the exception of one or two years, the Tyne never could compete in selling "mine" iron against the market price of the Glasgow makers. No practical man, therefore, was likely to be led into the expenditure of capital by a year or two's prosperity, with the knowledge of the superiority conferred on his Scotch competitors by their fields of black-band. Between the years 1840 and 1850, the cost of ironstone on the ton of iron was never, at the Birtley Iron Company's Works, less than 26*s.* 3*d.*, and this only when the trade was in an exceedingly depressed condition; 30*s.*, and as high as 34*s.*, was the more ordinary figure. The average selling price of iron at Glasgow over eleven years was within 6*d.* of the cost at the Birtley Iron Works, and to obtain this the owners must have charged the coal from their own pits at less than 2*s.* per ton laid down at the furnaces. During five years of the eleven, iron was cheaper at Glasgow than the cost at Birtley even with the coal supplied at 1*s.* 6*d.*, or thereabouts, per ton. In 1845, both the owners of the Walker and of the Tyne Iron Works sought to mend their position by looking for royalties of black-band in Scotland, and, in consequence, there was brought for some time a considerable quantity of that mineral to the river Tyne.

Matters were in this state when Messrs. Bolckow and Vaughan, who, in 1840, had built a rolling mill at Middlesbro', added at Witton Park, in 1846, the process of smelting to their operations. They were induced to do so by an offer of ironstone to be supplied from the coal-field near Bishop Auckland.

In these expectations, as had happened to their colleagues on the Tyne, they were disappointed, and, like them, they had recourse to Whitby. In one respect, however, their position differed from that of the ironmasters further north. In a voyage of fifty miles, ten miles more or less is a small sacrifice compared with securing a good harbour; but where the ironstone-measures were known to run close to the mouth of the river upon which the works were placed, it was obviously a matter of importance to draw the supplies of ore, or as much of it as could be obtained, from the nearest point. Examination of large detached masses which had fallen from the cliff led Messrs. Bolckow and Vaughan to Skinningrove on the coast, at which place, to their surprise, they found the bed had thickened out from $4\frac{1}{2}$ feet to nearly $14\frac{1}{2}$, and instead of 25 per cent. of iron it contained 31. So far was accident; but that firm, experiencing the usual inconvenience arising from an exposed place of shipment, sought for, and found in 1850, the position of the ironstone inland. It is not pretended that the merit of original discovery belongs to Messrs. Bolckow and Vaughan in reference to this extraordinary deposit of ore. On the contrary, Mr. Jackson, the father of the present owner of Normanby Hall, sent, in 1811, two waggons of it to the Tyne Iron Works. Mr. Bewicke, senior, was also, a year or two before its position inland was recognized by Messrs. Bolckow and Vaughan, aware of its existence near Guisbro'. Indeed, so early as 1839, a Mr. Neasham had despatched an entire cargo to the Devon Iron Works at Alloa, in Scotland, at which establishment it met with an indifferent reception, being tipped over the rubbish-heap very soon after its arrival. In the minds of none of these gentlemen, however, did the mineral excite that confidence in its value which the subsequent labours of the Middlesbro' firm ascertained it possessed, and to whom undoubtedly, therefore, is due the merit of having introduced it to the immensely important place it now occupies. The lias rocks contain other beds of ironstone, to which reference will be hereafter made, when the composition of the Main Cleveland seam, and its use as an ore of iron, are spoken of.

We have thus seen that, in a district embraced within the four counties of Northumberland, Durham, Cumberland, and Yorkshire, the coal-formation contains the usual clay ironstone; the mountain limestone has furnished to a limited extent some black-band and nodules of ironstone, and is now affording spathose ore and brown hydrated peroxide of iron, as well as very large quantities of the finest red hematite; lastly, in the lias beds of Yorkshire there are found inexhaustible deposits of argillaceous ore. Besides all these, and profiting by the return of light colliers, some small quantities of other ores, both foreign and British, are conveyed to the Tyne, but not to an extent to render them worthy of more especial notice. The composition of the various minerals now in use will be given when the subject of their metallurgical application comes, in its proper place, to occupy our attention.

Historical Account of the Manufacture of Iron in the North of England.—It is now proposed to show in what order, and in what manner, the various ores of iron, met with in the different geological measures in the North of England, have been made available in a metallurgical point of view.

Before entering on this part of his task, the writer would take the opportunity of expressing his acknowledgments to Mr. Hodgson Hinde, to whose antiquarian researches he owes some valuable information respecting the earlier production of iron in the North of England.

Notwithstanding the varied character of the different ores of the district under review, and the want of indication of metallic contents of some, the

property that even these have of "rusting" on exposure to air and moisture appears to have made known the existence of all at a very early period of our history. The labours of Hodgson, Wallace, and others leave little or no doubt that the smelting or reduction of iron ore was carried on to a considerable extent in this part of the country during its occupation by the Romans. Vast heaps of iron scoriæ may be seen on the moors in the parishes of Lanchester and Chester-le-Street, in the county of Durham, and in the valleys of the Reed and the Tyne, on the mountain limestone, in Northumberland. It is remarkable that none of these are very remote from one or other of the Roman stations which are scattered over these two counties. The same observations respecting an early use are, to some extent, applicable to the lias ironstone; and, no doubt, proper investigation would indicate a similar state of things wherever iron ores were near the surface, and the state of society required the metal they contained. That furnaces, or "bloomeries," were continued or re-established in some of the same situations is proved by an inquisition of the death of Gilbert d'Umfraville, Lord of Redesdale. In the catalogue of his possessions, A.D. 1245, there are mentioned, "forgiæ quæ reddunt ferrum, quod reddit per annum iiij l ijs;" and that ironworks existed in the county of Durham in the early part of the 17th century appears from a curious tract written in 1629, entitled "A Relation of some Abuses committed against the Commonwealth, composed especially for the county of Durham." The author, who signs his initials "A. L.," instances as the first abuse the great destruction of timber, chiefly for the sake of bark for the tanneries, but in one instance, at least, for smelting-operations. He says, "There is one man, whose dwelling-place is within twenty miles of the city of Durham, who has brought to the ground (to omit all underwood) above 30,000 oaks in his lifetime, and (if he live long enough) it is doubted that he will leave so much timber in the whole county as will repair one of our churches if it should fall, his iron and lead works do so fast consume the same."

Hitherto, of course, all these smelting-operations have reference to the small bloomery or hearth in which, with a little ore and some charcoal blown by the wind in exposed situations, or subsequently by rude bellows, a "bloom" of malleable iron was obtained*.

The German colony of ironworkers at Shotley Bridge established themselves at that place in the reign of William III. At some time or another afterwards a small high-blast furnace, five or six feet in the boshes, was erected there, the remains of which, according to information received, are still visible. Wallis, in his 'History of Northumberland,' published in 1769, mentions an ironwork which existed some years previously at Lee Hall, near Bellingham, under the management of a Mr. Wood, "who made a good deal of bar iron; but, charcoal becoming scarce, he removed to Lancashire, where he attempted (unsuccessfully) to make it with pit coal." Although bar iron only is mentioned, there is no doubt, from the remains still existing, that

* This simple mode of smelting, viz. the bloomery, is the one which appears to have been universally adopted in the first instance for obtaining iron. Captain Grant, who has recently returned from his expedition to the source of the Nile, found the inhabitants of the Land of the Moon gathering small nodules of ironstone from the sides of the hills, and smelting them on the bare ground in a charcoal fire. The blast was produced by two or four persons working each a small bellows formed of wood and goat-skins. At the end of the wooden bellows pipe was a short tube, or tuyère, of baked earthenware, which conveyed the compressed air to the fire. The bloom resulting from the operation was beaten into a thin bar and then drawn out into wire, which was chiefly used for ornamental purposes.—*Private Letter to the Writer.*

Wood also produced pig iron. Charcoal iron was also smelted from some of the bands of clay ironstone at Bedlington, where the old calcining-kilns are still visible, or were so until very recently. No iron, however, has, as far as can be ascertained, been made there for more than a hundred years.

The inroads which iron-smelting, together with other metallurgical operations, &c., had made upon the forests were such, that in the reign of Queen Elizabeth four Acts of Parliament were passed to restrict the consumption of timber, especially when applied to the manufacture of iron. To supply the deficiency thus occasioned, schemes were proposed so early as 1612 by Sturtevant, and subsequently in 1621 by Dud Dudley, for smelting iron with pit coal. The unsuitability, however, of the arrangements in use for smelting with charcoal when applied to mineral fuel, in all probability delayed this important amelioration taking effect for a hundred years after its first suggestion by Sturtevant. The small furnaces and bellows of very limited power, which did very well with charcoal, would be literally useless when applied to coal or coke. After various ineffectual attempts by Buck and others, about 1713 the Darbys of Staffordshire reduced the application of pit coal to one of practical utility in that county. Darby's progress, however, must have been slow, and his success limited; for the number of blast-furnaces in the country had, in the meantime, decreased from 300 to 59, so that in 1740 the make of pig iron in England had fallen to 17,850 tons, from about 180,000 tons, the chief portion of our requirements being imported from Sweden and Russia. To Mr. I. Cookson, who had recently purchased the Whitehill estate, near Chester-le-Street, the merit belongs of erecting and working the first blast-furnace with coked coal in the North of England. The Whitehill furnace was 35 feet high, 12 feet across the boshes, and produced 25 tons of iron per week. The blast was supplied by a bellows, worked by a water-wheel, placed on Chester Burn. Its mode of supply of ironstone was from the thin bands on Waldridge Fell and from Robin Hood's Bay, as has been already mentioned. The coal, of course, was obtained from the immediate vicinity. Mr. Joseph Cookson, a descendant of the founder of pit-coal smelting in this district, has given many curious particulars respecting this early attempt. The iron was used for colliery castings, and latterly for Government ordnance. Frequent interruptions for want of water to drive their wheel led at length to the furnace being "gobbed," and ultimately abandoned, about the close of the last century.

Whatever advantages, in point of minerals, any district might stand possessed of, its power for turning them to profitable account depended at that time on the existence of a fall of water sufficient to drive the needful blowing-apparatus. The discoveries of Watt prevented the want of hydraulic power being any longer an impediment, and in a short time the obedient steam-engine was appointed to supply the necessary blast to iron-furnaces. Notwithstanding the poverty of our coal-field in ironstone, the high price of iron—£8 per ton—and the small quantity of ore required for a furnace when forty tons of iron was the usual week's make, induced the Tyne Iron Company, in 1800, to erect their two furnaces and a steam blowing-engine at Lemington. An idea of the cost of manufacturing pig iron in those days is not without interest as illustrative of the disadvantages of this coal district as an iron-field. The particulars are kindly furnished by Mr. G. Clayton Atkinson, one of the present members of that firm, so that their correctness may be relied on:—

Ironstone	3·44 tons at	16s. 1d.	£2 15 5		
Hematite ore	·11 „	31s. 6d.	0 3 5		
				£2 18 10	
Flux (chalk)	1·38 „	2s. 6d.		0 2 9	
Coke	2·40 „	12s. 5d.		1 9 9	
Labour, &c.				0 14 2	
				£5 5 6	

These details are of the year 1812, when cold blast alone was employed. The make from one furnace was 2547 tons; equal to 49 tons per week. The ironstone, with the exception of 806 tons of "beach stone," was all the produce of the thin bands of our coal-measures.

In 1825 pig iron rose in value to the unprecedented price of £12; and as a considerable portion of the stone smelted by the Tyne Iron Company was the produce of pits at Urpeth and its neighbourhood, Messrs. Perkins, Hunt, and Thompson, who were extensively engaged in coal-mining in that locality, blew in two furnaces, in 1830, which they had built at Birtley. Their operations, like those of their predecessors at Lemington, exhibit, with equal force, the absence of the elements of success in our coal-field for the manufacture of iron even when the fuel was supplied to the furnaces at the low rate of 2*s*. per ton or less. The following is copied from their cost-book, and represents the workings for two furnaces for 1835, when hot air was used—an improvement introduced at Birtley in 1831. The make was 4390 tons, or only 42 tons for each furnace per week. The cost per ton of iron was, for

Ironstone	£1 18 1¼
Flux (chalk)	0 2 7
Coal (5 or 6 tons probably)	0 7 0½
Labour, &c.	0 14 2¼
Sundries	0 14 2
Total	£3 16 1

In 1836, the furnace at Wylam was put into blast by Messrs. Thompson Brothers to smelt ironstone expected to exist in great abundance there, as has been already explained.

We have now arrived at that period in our history of the iron-trade which was followed by a gradual but, ultimately, an entire change in the sources from which the furnaces of this district derived their supplies of ironstone. So early as 1836 a cargo of that ore, which in time displaced all others at the then existing works on the Tyne, so far as local ironstone was concerned, was sent from Grosmont, near Whitby, to Birtley. In the year 1833, and up to 1839, pig iron had ranged from £4 10*s*. to as high as £9 per ton in Wales. The demand for iron in this neighbourhood was so vastly on the increase, that the ores of the coal strata could not meet the growing requirements, and the Whitby stone had not inspired much confidence either for economy or quality of the iron it produced. In consequence, speculators began to pay attention to those deposits of ironstone spoken of as being connected with the mountain limestone. Ridsdale was the place selected by Mr. Stephen Reed, Mr. Thomas Hedley, and others, where the stone existed, as has already been described, and where coal could be obtained from a seam from 2 to 2½ feet thick, situated in the same geological formation.

Although pig iron had fallen in 1840 to £3 12*s*. 6*d*. at Glasgow, and in 1841 was selling at £3 5*s*. per ton, a second work, to smelt the same bed of ironstone with the coal 2½ feet thick, lying 70 fathoms below the ironstone, was put in blast at Hareshaw; a second furnace was subsequently built at

Ridsdale, and two more at Hareshaw. There is no doubt that the iron produced from this bed of ironstone was of a very excellent description. Both works, however, were nearly twenty miles from a railway, and twenty more from a market; so that their iron cost, according to Mr. T. J. Taylor, 12*s.* per ton for carriage to the consumer. After some years of fruitless struggle to meet the competition offered by Glasgow, both of these establishments were closed and finally dismantled.

About 1840, Messrs. Bigge, Cargill, Johnson, and others, who had purchased from the projectors of the Ridsdale Works that concern, had their attention directed to the beds of ironstone described as lying in the coal-measures near Shotley Bridge. A pair of furnaces were speedily erected and set in blast. A larger company was formed, and an immense establishment was constructed. Twelve blast-furnaces were built, large rolling-mills and all the necessary mines, mining villages, &c., followed in rapid succession. Until 1850 the furnaces went on devouring the minerals found in the neighbourhood at an alarming pace, having in the meantime made extensive trials of those from the lead-veins of Weardale. In 1850, the recent discoveries in Cleveland promised relief from the impending famine; and in a very short time, in spite of a distance of about fifty miles, the ironstone from that district, with some hematite for a mixture, entirely superseded the stone lying adjacent to the furnaces.

In 1842, Messrs. Losh, Wilson, and Bell, who for fifteen years had been making bar iron, built a blast-furnace at Walker for producing forge pig by smelting their mill-furnace cinders with Whitby stone, and this was followed by a second one in 1844; so that these were the first furnaces ever built expressly for smelting the recently discovered ironstone at Whitby.

About this period, Mr. Charles Attwood, in concert with Messrs. Baring and Co. of London, purchased a small furnace then recently erected at Stanhope by Mr. Cuthbert Rippon, and built five others at Tow Law for smelting the "rider ore" (carbonate and oxide) of the lead veins. There is no doubt that, owing to the extreme irregularity of this kind of material, immense labour and expense were at first incurred, and, as regards the quality of the produce, frequently with very unsatisfactory results. Better acquaintance, however, with the veins and their contents has enabled that firm now to produce iron of a very high class—so good, indeed, as closely to resemble in composition and quality the celebrated German "Spiegel Eisen." For bar-iron purposes it bears a high name, and has, like its prototype in Germany, been found well adapted for the manufacture of the finer kinds of steel—an application, as is well known, confined exclusively to the purest descriptions of metal.

In 1846 Messrs. Bolckow and Vaughan erected the furnaces at Witton Park, in the Auckland district, for smelting ironstone expected to be obtained in that vicinity. We have already heard how these hopes were disappointed and Whitby resorted to, as it had been by almost every furnace-owner in the North.

Although only remotely connected with our subject, it may as well be mentioned that a company of gentlemen had erected at Cleator Moor, near Whitehaven, a couple of blast-furnaces for smelting the hematite iron-ore of that district, an example which has been somewhat extensively followed since. The iron made is of good quality, and, the ore being rich, an immense quantity, as much as 500 tons weekly, or more, is said to have been run from one furnace.

To avoid interrupting the remainder of our subject, which will hereafter

be confined almost exclusively to the Cleveland stone, mention may be made of other trials to render available the bed of ironstone-nodules of the mountain limestone. This was attempted at Brinkburn, on the Coquet, but after a very short trial the works were closed. Another experiment was made at Haltwhistle with a similar view, but it also was abandoned soon after the erection of the works.

At Bedlington two furnaces were constructed to smelt the same bands, formerly used at the charcoal-works in that locality, with an admixture of Yorkshire stone, mill cinder, and other materials, but these also were only a short time in operation.

We have now arrived at the period when the newly discovered Cleveland bed of ironstone was about to supersede all other modes of supply of this mineral, and the present will therefore be a convenient opportunity of estimating the position of the iron-trade previous to its introduction. This will be most readily done by glancing at a list of the furnaces then in existence, which were as follows:—

Furnaces.	Proprietors.	No.	Description of Ironstone used.
Lemington	Tyne Iron Co.	2	Whitby stone, black band, and hematite.
Birtley	Birtley Iron Co.	2	Whitby stone, &c.
Wylam	Bell, Brothers	1	Do. black band, hematite, &c.
Ridsdale	Ridsdale Iron Co.	2	Nodules from mountain-limestone formation.
Hareshaw	Hareshaw Iron Co.	3	Do. do.
Shotley Iron Works.	Derwent Iron Co.	14	Bands of ironstone from coal-measures, and hematite.
Walker	Losh, Wilson, and Bell.	2	Whitby stone, black band, hematite, &c.
Tow Law and Stanhope.	Weardale Iron Co.	6	"Rider ore" from lead-veins, and a portion from coal-measures.
Bedlington	Longridge and Co.	2	Whitby ironstone, and a portion from coal-measures.
Witton Park	Bolckow & Vaughan	4	Do. do.
	Total	38	Furnaces.

The entire make of all these furnaces would never exceed 150,000 tons per annum during the period under consideration.

We have now (*i. e.* A.D. 1851) brought up the account to what substantially in principle is the position at present occupied by the manufacture of iron, on, or in connexion with, the Newcastle and Durham coal-fields. In pursuing the narrative, illustrating the development of the trade, it will be convenient to give, in the order they arise, some account of the character and composition both of the raw materials used and of the products obtained.

Coal.—Notwithstanding the varieties of coal which occur in the northern coal-field, the whole, with few exceptions, are more bituminous in character than the produce of other localities in this country. North of the Ninety-fathom Dyke is the district where the Low Main of the Tyne (Hutton Seam of the Wear) furnishes the least caking coal we possess; but even here the small coal, when coked, loses all trace of its original form and leaves the ovens as large masses of coke. At Wylam, Walbottle, and other places, a thin layer of a dry-burning splint coal does occur in connexion with a seam of a highly caking description, but the entire quantity of it, and of any other similar variety, is very insignificant. The caking property, although very valuable for many purposes, entirely unfits the coal of this district for use in the raw state in our blast-furnaces, where its fusing property, by impeding the blast, causes the contents of the furnace to hang and slip, and thus to descend at

irregular intervals. Against this disadvantage, however, possessed by our coal, may be placed the extreme hardness and strength of the coke it produces, which is thereby rendered capable of resisting the crushing effect of a high column of materials as they exist in our blast-furnaces. An experiment at the Clarence Works showed that a cube of coke 2 inches on a side supported a weight of 25 cwt. when cold, and 20 cwt. when hot, before it was crushed. Dr. Richardson gives the following analyses of coal from this and other districts, the latter being given for the sake of comparison:—

	Locality.	Sp. gr.	Carbon.	Hydrogen.	Nitrogen	Sulphur.	Oxygen.	Ash.	Percentage Coke left by Coal.
18 Samples,	Newcastle	1·256	82·15	5·31	1·35	1·24	5·69	3·77	60·67
36 do.	Wales	1·315	83·78	4·79	·98	1·43	4·15	4·91	72·62
8 do.	Scotland	1·259	78·53	5·61	1·00	1·11	9·69	4·03	54·22
7 do.	Derbyshire	1·192	79·68	4·94	1·41	1·01	10·28	2·65	59·32

The purity of the coal is by no means an infallible indication of its fitness for the manufacture of a suitable coke for iron-furnaces. Not only is comparative freedom from ash and sulphur indispensable, but we must have concurrently the power which depends on some circumstance we do not clearly understand, of producing coke sufficiently compact to come down to the region of fusion in our furnaces without being much crushed on its way.

To form an idea of the extent to which ash and sulphur exist in the coke of the South Durham coal-field, the following analyses are extracted from the Clarence Laboratory journal:—

Ash per cent.	Sulphur per cent.
5·86	0·58
5·79	0·68
7·54	0·77
9·00	0·44
8·33	0·50

As a rule, 6 per cent. of ash and about ·60 of sulphur may be considered as the average analytical results of the best coke of the district just quoted. Following the example of our neighbours abroad, plans have been introduced into this neighbourhood of submitting coal of an inferior description to a washing process, by which, where the earthy matter is not part and parcel of the coal itself, a very large quantity of impurity is easily removed.

Limestone.—A very few words will exhaust this section of the subject. In certain districts the magnesian limestone, although differing little in colour, &c., from the rock in other localities, is nearly entirely carbonate of lime, and the mountain limestone almost invariably, from its purity, satisfies the conditions required by the iron-smelter. These two, but principally the latter, with a little chalk, brought by coasting-vessels as ballast, constitute the flux in the iron-furnaces. The following analyses from the Clarence Laboratory show the composition of

	Mountain Limestone Harmby.	Magnesian Limestone. Raisby Hill.	Chalk from South of England.
Insoluble in Hydrochloric acid	2·00	·95	1·96
Peroxide of Iron and Alumina	·98	·40	1·24
Lime	53·35	54·62	53·84
Magnesia	1·08	·43	·63
Carbonic acid	43·02	43·42	42·99
	100·43	99·82	100·66

The chalk contained 21 per cent. of water.

Ironstone of the Lias.—It will be foreign to the intention of the present communication to attempt anything like a minute description of the district

over which the deposit of ironstone, embraced within the title of this section, is found. Mr. John Marley, whose name has been, from the first, associated with its discovery in the neighbourhood of Middlesbro', and who has devoted much attention to its geological position and extent, and the late Mr. Joseph Bewicke, to whom a long practical acquaintance with the subject gave abundant opportunity of studying this question, have both written on the subject at considerable length. To their works—the former in the Transactions of the Northern Institute of Mining Engineers, and the latter in a work on the Cleveland Ironstone—those persons who desire more detailed information are referred.

It may be briefly stated, however, that Mr. Bewicke gives the dimensions of the field of ironstone as thirty miles by sixteen, from which he deducts sixty miles for denudation, giving a net area of 420 square miles. The brother and partner of the writer, Mr. John Bell, who possesses a very complete knowledge of the district, prepared models and maps of the country which agree pretty closely with these estimates. Mr. Bewicke roughly considers the yield to be 20,000 tons per acre, and hence infers that close on 5000 million tons are contained in the Main Cleveland Seam, within the limits laid down*. We have already seen, in the preliminary account of this bed of ironstone, how varying in thickness it is. In some places, also, it becomes more or less split up by bands of shale, a circumstance which of course interferes greatly with its commercial value. Commencing with Grosmont, near Whitby, where it was first wrought in a systematic way, there are found two seams of ironstone, known as the Pecten and the Avicula bands. The former consists of 3 feet of ironstone, divided in the middle by a bed of shale $1\frac{1}{4}$ foot thick. Separated from this by 30 feet or more of shale is the other seam, the Avicula, embracing $4\frac{1}{2}$ feet of ironstone, along with 2 feet of shale; and it is by these two bands uniting, as well as increasing in thickness, that we have further north the Main Cleveland Seam, as it is termed. In the northern portion of the field considerable irregularity in character is also observable. At Codhill the bed has an extended height, but is so interspersed with foreign matter that it is found necessary to confine the mining to a section of $5\frac{1}{2}$ feet; and the produce, from the circumstance of more or less shale bands running through the ironstone itself, is only about 28 per cent. of metal. A little to the east of Codhill are the Belmont Mines, where the shales thin out, and in consequence the yield of iron is about 30 per cent., the seam at the same time having increased in height to $7\frac{1}{4}$ feet. At Skelton, still further east, a marked improvement, both in thickness and in quality, is again discernible. The workings there are frequently 10 feet high, and a recent analysis of the entire section of stone gave above 36 per cent. of iron. The north side of the Vale of Guisbro' is formed by an elevated ridge of land separating this valley from that of the Tees. At the western edge of this ridge are the Normanby mines, where the stone is worked at an average thickness of about 8 feet, containing $31\frac{1}{2}$ per cent. of iron. There is a general dip of the seam to the east from this point, and in its progress in that direction there is a gradual increase in thickness, and a little improvement in percentage of iron. It continues in this way past Eston and Upleatham, until it reaches Rockcliffe, where it attains a thickness of nearly

* In an estimate recently made by the writer, based on the researches of Messrs. Hugh and T. J. Taylor, T. Y. Hall, &c., there would appear to be in our northern coal-field six thousand million tons of coal left for future use; so that there is just about fuel enough in the one district—reserving it for that purpose exclusively—to smelt the ironstone of the main seam of the other.

18 feet, after which it splits again into bands, and, as far as is known, resumes towards the east and south the character formerly observed as attaching to it at Grosmont, near Whitby.

From the details just given it will be seen that, although the quantity of ironstone in the Main Cleveland Seam is practically inexhaustible, the portion which, in recent years, has yielded such immense quantities of rich mineral, as far as we can at present judge, occupies comparatively a very limited area. Commencing at Swainby, near Osmotherley, which is the most western point where the bed is worked, its thickness is not much above 3 feet, and the percentage of iron under 28. It improves gradually in a north-eastern direction past Kildale, where a working was attempted, and abandoned, by the writer's firm. It is not until we reach Codhill, thirteen miles from Osmotherley, that the seam is considered worth extracting; and a line from this point to Rockcliffe, on the coast, a distance of twelve miles, will probably be found as forming the southern boundary of the best stone; so that, after making the necessary allowance for denudation, twenty to thirty square miles may be assumed as the extent of the area, of which a considerable portion lies at a great depth.

Much more irregular in its features is the so-called Top Seam. At Normanby and Eston little more than its position can be recognized, and throughout the entire field it varies from a few inches to many feet in thickness. In richness of iron it is not less changeable, giving from 20 to 35 per cent. of metal, according to the locality from which the sample may be taken. In the Main seam there exists a certain degree of uniformity, even in the change of thickness and richness; but in the Top seam both alternate very frequently in a most unlooked-for manner. On the western side of the district Ingleby Greenhow is the most northern, and indeed the only place where the Top seam has been wrought in that direction. In the mine there its thickness was 2 feet, and its richness in iron 34·75 per cent. On the other side of the valley it thinned away to a few inches, containing 37·65 per cent. of metal. Near Osmotherley the seam is several feet thick, and in it a few inches at the top contain 41 per cent. of iron; these are succeeded by 3 feet of stone, with 24·5 per cent., lying upon the top of 10 feet, giving 16·70 per cent. of iron. On the east coast, at Port Mulgrave, Messrs. Palmer formerly worked a small district of the Top seam 4 to $4\frac{1}{2}$ feet thick, which on analysis gave 30·99 per cent. of iron. In Goadland Dale, Glazedale, Fryup Dale, and Danby Dale this seam varies from 5 feet to 8 or 9 feet in thickness, and yields from 20 to 25 per cent. of iron. In one case it is as low as 9·33, and in another case as high as 30·11 per cent., but both of these results were from a very limited area. Unless the magnetic ironstone worked at Rosedale Abbey is a portion of this Top seam, about which some doubt has been expressed, all the workings in connexion with this bed have been abandoned from the causes just enumerated.

A word or two respecting the mode of extracting the ironstone from the Main Cleveland Seam in the northern portion of the field, *i.e.* near Middlesbro', will probably not be considered as altogether superfluous. There is a portion of the bed at the top 3 feet thick, over and above the heights of the seam formerly given, and separated by a parting from the remainder of the bed, which parting varies from being a mere point of separation to a thickness of 6 or 7 inches. When it attains this latter thickness, or even less, its contents are so impregnated with bisulphide of iron as to give 28 per cent. of sulphur. This band, being easily detached from the ironstone, was applied in the chemical works at Washington as a substitute for ordinary pyrites, and continued to be so used until a manufactory at Middlesbro' was able to consume

all the produce of the district on the spot. An analysis of the 3-feet and of the sulphur band will be found in the table hereafter given. The 3-feet is left in the workings to form the roof of the mine. The remainder of the seam varies from 8 to 10 feet in height, and indeed occasionally reaches 16 feet, or even more. In extracting the stone, headways are driven 9 feet wide and 90 feet apart, from which, at intervals of 30 feet, boards are excavated 15 feet wide. By this system "pillars" are left 90 feet long by 30 feet wide. When the limits of the royalty are reached, or when, from any other cause, it is deemed necessary to work the pillars, they are removed, with something like a loss of 10 per cent. of their contents, so that in a good working, free from faults, the whole of the ironstone, within perhaps 7½ per cent., can be brought away.

The following tabulated results of analyses will give a correct idea of the component parts of the Main Cleveland Ironstone Seam, taken from that portion of the district where it is found in the greatest perfection:—

	Normanby, average of seam worked.	Eston.	Upleatham.
Protoxide of iron	38·06	39·92	37·07
Peroxide of iron	2·60	3·60	4·48
Protoxide of manganese	·74	·95	—
Alumina	5·92	7·86	12·37
Lime	7·77	7·44	4·67
Magnesia	4·16	3·82	2·69
Potash	—	·27	—
Carbonic acid	22·00	22·85	23·46
Silica	10·36	8·76	10·63
Sulphur	·14	·11	—
Sulphuric acid	—	—	—
Phosphoric acid	1·07	1·86	1·17
Organic	—	—	—
Water	4·45	2·97	3·36
	97·27	100·41	99·90
Metallic iron	31·42	33·62	31·97
Authorities	Clarence Lab.	Dick. Geol. Survey.	Crowder.

	Skelton.	Skelton.	Normanby 3 ft. roof.	Sulphur band.
Protoxide of iron	45·60	44·31	33·86	9·97
Peroxide of iron	—	—	·47	—
Protoxide of manganese	·75	—	·96	—
Alumina	8·51	11·66	6·92	8·47
Lime	6·31	4·66	5·82	·49
Magnesia	3·85	2·33	3·84	1·07
Potash	—	—	—	—
Carbonic acid	21·30	27·25 includes water.	25·00	—
Silica	10·54	7·66	15·24	10·94
Sulphur	—	1·04	·40	28·37* 24·82
Sulphuric acid	—	—	—	—
Phosphoric acid	2·92	1·80	1·40	—
Organic	—	—	—	—
Water	—	—	3·69	13·20
	99·78	100·71	97·60	97·33
Metallic iron	35·46	34·43	26·66	—
Authorities	Clarence Lab.	Clarence Lab.	Clarence Lab.	Clarence Lab.

The relationship existing among the earthy constituents of the Cleveland

* Sulphur and iron, as bisulphide of iron—28·37 sulphur, 24·82 iron.

ironstone, it will be seen, varies somewhat in different localities. This is not to be wondered at, for in fact the seam itself in the same section is by no means uniform in its composition. A moment's inspection of the furnaces working the ironstone of the district enables a practised eye to perceive a very marked difference in the general character of the slag compared with that usually seen at ironworks. Although it flows hot and fluid, it is extremely stony in its fracture, with scarcely a vestige of a vitreous nature. A very short comparison of the relationship which the earths bear to each other in ores of other parts of the country with those under examination will explain this. The following may be instanced:—

	Low Moor	Parkgate.	Butterley.	Brierly.	Stanton.	Cleveland.
Silica	60	44	54	60	50	34
Lime	9	13	11	9	13	27
Magnesia	8	19	9	7	17	14
Alumina	23	24	26	24	20	25
	100	100	100	100	100	100

The following analyses show the composition of slags produced at different works:—

	Slag from Wales. Cyfarthfa.	Wales. Dowlais.	Staffordshire. Dudley.	S. Yorks. Low Moor.
Silica	45·00	43·2	38·76	43·5
Alumina	16·5	12·0	14·48	11·0
Lime	27·7	35·2	35·68	33·6
Magnesia	4·5	4·0	6·84	3·6
Protoxide of iron	3·6	4·2	1·41	8·1
Sulphur	1·4	—	·98	·8
Potash	—	—	1·11	—
	98·7	98·6	99·26	100·6
Authorities		Berthier.	Dr. Percy.	

Those from Cyfarthfa and Low Moor were analyzed under the writer's eye. In the case of Low Moor the iron was chiefly metallic.

On comparing the composition of the slags from the Welsh, Staffordshire, and South Yorkshire works, just given, with those from the furnaces in Cleveland, the great dissimilarity in constitution will at once be perceived, and a little further examination will show that, with the composition of our ores, no mere addition of lime can ever imitate the vitreous slags of those localities just mentioned.

The following analyses illustrate this:—

	Slag from Clarence.	Clarence.	Clarence, previous one repeated.	Clarence.	Ormsby.
Silica	30·40	27·80	27·68	27·65	29·92
Alumina	20·72	22·28	22·28	24·69	21·70
Lime	36·88	40·45	40·12	40·00	38·72
Magnesia	4·25	7·21	7·27	3·55	6·10
Protoxide of iron	3·64	·61	·80	·72	·32
Do. manganese	1·02	trace	·20	·35	·80
Sulphur	1·34	2·00	2·00	1·95	1·61
Potash	·50	—	—	·46	—
Soda	—	—	—	·99	—
Phosphorus	—	trace	—	·26	·07
	98·75	100·35	100·35	100·62	99·24
Authority	Clar. Lab.	Clar. Lab.	Clar. Lab.	W. Crowder.	Clar. Lab.

There is one circumstance connected with the composition of these slags which may have some interest in a chemical point of view, inasmuch as it may throw some light on a subject not yet very deeply examined, namely,

that of the comparative volatile nature of the earths, or of the comparative facility with which they are decomposed and vaporized. In all the analyses hitherto made by the writer, the composition of none of these slags corresponds with the amount of earthy matter introduced into the furnace; thus, in the three specimens of slag from the Clarence furnaces, the silica, alumina, lime, and magnesia bear the following average ratio to each other, as expressed in whole numbers:—

Silica.		Alumina.		Lime.		Magnesia.		
30	+	24	+	41	+	5	=	100

After analyzing the Normanby ironstone which was used about that time, and adding to its earthy constituents those introduced in the coke and limestone, the slag, by calculation, should have been, as regards the above-named elements, composed of—

Silica.		Alumina.		Lime.		Magnesia.		
29	+	16	+	46	+	9	=	100

The analysis in the School of Mines would, it is true, give a somewhat different result, but one which, nevertheless, does not correspond with actual examination of the slags, even had a similar quality of mineral been in use at Clarence. The Eston stone smelted with the same kind of coke and limestone should have given slags containing the earths in the following proportions:—

Silica.		Alumina.		Lime.		Magnesia.		
28	+	18	+	45	+	9	=	100

There escapes, as may be easily seen, from the furnaces on the Tees, &c., vast volumes of white vapour, which condense, or partly condense, with great facility. That there is a difference in the readiness with which it does this may be inferred from the fact, that while large quantities of condensed matter are intercepted in the pipes for leading the gas to the boilers, a great amount travels many yards before it reaches a lofty chimney, from which it escapes as a white cloud, and this cloud goes a long distance in the atmosphere before it is finally dispersed. Nothing short of entire interception of the vapour will enable us to judge whether the discrepancy between calculation and fact can be reconciled. The writer is now engaged in arranging a steam-pump which, by continued exhaustion through water or otherwise, will effect, no doubt, complete condensation of each of the component parts of this fume, when some light may be thrown upon the nature of the volatilized portions of the minerals used in our blast-furnaces.

This fine dust has been examined at the Clarence Laboratory, and although the analysis proves nothing, having been taken at one place only in the connecting pipes, a statement of its composition may not be devoid of interest. It gave—

Silica and sand	34·82
Alumina	16·00
Lime	12·15
Magnesia	·57
Peroxide of iron	8·20
Oxide of zinc	4·60
Sulphuric acid	8·80
Potash...	·40
Soda	6·85
Chlorine	1·56
Water	5·60
	99·55

From a more recent examination of the fume, taken at different distances from its point of exit from the furnace, the varying proportion of lime would indicate that this earth maintains the condition of vapour longer than the other constituents of the condensed matter:—

At 30 yards from the point of exit the dust contained				9·0 per cent. of Lime.	
At 60 do.	do.	do.		12·5	do.
At 130 do.	do.	do.		14·0	do.

In order to supply that deficiency in silica noticed as existing in the slags, and which might possibly affect the quality of the iron itself, there was added to the charge at the Clarence Works a siliceous mud, and subsequently, at Eston, freestone, by Messrs. Bolckow and Vaughan. A vitreous slag resulted; but no very marked improvement being noticed in the iron, the addition was discontinued.

Temperature of Blast.—The uniform practice in the whole district is to blow the furnaces with heated air. Sufficient data are not possessed to enable us to speak with any degree of certainty respecting the application of cold blast; but, as far as actual experience goes, it is in favour of the idea that the lias ironstone would prove very intractable under that mode of smelting. In the year 1841, from some reason or another, cold air was used during four months at Birtley. The furnaces only ran 42 tons per week of white iron, produced by a consumption of 3½ tons of coke to the ton. At Clarence an attempt was made recently to operate on the Cleveland ore in the same way; twice the quantity of coke was used which is required when making foundry iron, and only white pig was obtained.

A more elevated temperature being wished for than is easily commanded by means of heated iron pipes, various experiments were tried at the Clarence works, and ultimately Cowper's stoves were introduced. In these, by an alternate system of heating a mass of brickwork in closed vessels of iron, and passing the air through the same, a temperature of 1000° F. and upwards in the blast was obtained. The condensation, however, of the furnace-fume, the apparatus being heated by the waste gases, so interfered with the efficiency of the apparatus that the system was modified. Previous experiments were then continued, in which an arrangement of clay pipes, iron pipes, and forge cinders was made to replace the bricks. This was a great improvement; the temperature of the air was increased up to 1200° F., and the tubular arrangement permitted the apparatus to be more easily cleaned. In time, however, the same inconvenience from the condensed fume interrupted the value of the results, and the plan was abandoned. At no time was the high temperature maintained with that regularity upon which success alone depends. Enough, however, was ascertained to give encouragement to the idea that a steady increase of 500° or 600° in the blast would have been serviceable.

To avoid the inconvenience of the flue-dust, Messrs. Cochrane erected large gas generators to obtain carburetted hydrogen and carbonic oxide from the imperfect combustion of coal. The writer is unable to say what have been the advantages attending this mode of operating. The loss of heat from such a plan of applying coal, and other sources of expense, will probably be a serious impediment to the full measure of usefulness of the system*. At the Wylam and Wear Ironworks the writer has introduced an arrangement by which the blast is heated by means of the waste heat from the coke ovens.

Shape of the Blast Furnaces.—In shape, our blast-furnaces present no novelty worthy of notice. The width of the boshes varies from 14 to 18 feet, and the height from 42 to 50 or 55 feet, in one case 75 feet having been reached with beneficial results. An average proportion will, probably, be

* Since the foregoing was written, Messrs. Cochrane have informed the writer that they experience no difficulty in maintaining a temperature of 1150° in Cowper's stoves, which they have had in operation for two years, and that they thereby effect an economy of 5 cwt. of coke in the blast-furnace on the ton of iron, as compared with the furnaces using air heated in the ordinary way. Messrs. Cochrane also state that in any future furnaces they propose using this form of apparatus.

three diameters of the boshes to the entire height; but no great importance can be attached to this ratio, inasmuch as the furnaces continue to work well long after the destruction of the lining has greatly altered the dimensions just given. One attempt has been made here to employ Alger's furnace, in which the circular horizontal section is replaced by one of an elliptic character. In this form the iron is tapped, and the slag allowed to run, from the back as well as from the front of the furnace. At the Stockton Ironworks, where the system has been tried, the major axis of the ellipse is 12 feet and the minor $5\frac{1}{2}$ feet in the hearth; the higher part of the furnace (which is an old one altered) remains circular. The owners do not find it expedient to work it from both sides, as is proposed by the patentee, neither has it the large dimensions he recommends. It is therefore premature to offer any opinion on the merits of the plan from the experience of this district, which, however, hitherto has not been such as to warrant the conclusion that a departure from the old shape is advantageous. The blast in the North of England is introduced generally by three or four tuyères, at a pressure varying from 3 to 4 lbs. per square inch, and at a temperature of about 600° to 700° F. The production of a furnace is from 200 to 220 tons weekly, although more than this quantity has been frequently obtained.

Quality of Iron from Cleveland Ironstone.—Notwithstanding the composition of the slags already spoken of, the furnaces drive with great ease and rapidity—the cinder flowing, when the make is foundry iron, perfectly liquid, and of an intense white heat.

For foundry purposes the Cleveland iron was at first objected to from its chilling quickly in the "ladle," when compared with the makes of Scotland, and producing more "scum" than the metal from that country.

The writer had this scum analyzed at the Clarence Works, and found it to consist of—

Silicate of iron	42·10
Protoxide of iron	8·32
Iron	42·02
Carbon	1·93
Protoxide of manganese	2·82
Lime	·49
Magnesia	·10
Phosphorus	1·11
Sulphur	·23
Titanic acid	·88
	100·00

The furnaces of this district have little tendency to produce what is technically known as "glazy iron." Some years ago one of the Clarence furnaces, however, did run a quantity of this kind of metal. Two samples of it were analyzed, and their composition was ascertained to be as follows:—

	No. 1 Pig.	No. 1 Pig.
Iron	88·18	90·70
Carbon combined	·79	·71
Do. uncombined	2·59	2·68
Silicon	5·13	5·13
Manganese	·77	·56
Sulphur	·17	·23
Phosphorus	1·12	1·12
Titanium	·26	·18
Calcium	·22	·20
Magnesium	·06	·03
Authority............ Clarence Laboratory.	99·29	101·54

Silicon evidently constitutes the chief difference between the two samples given above and the iron usually produced in the neighbourhood.

The composition of fifteen samples of ordinary iron smelted from the Cleveland lias-stone is exhibited in the annexed table of analyses. These examinations, with two exceptions by Mr. Crowder, have all been performed in the Clarence Laboratory.

	Clarence. No. 1 Pig.	Clarence. No. 1 Pig.	Clarence. No. 1 Pig.	Tees. No. 1 Pig.	Cleveland. No. 1 Pig.	So. Bank. No. 1 Pig.
Iron	93·03	92·68	94·13	92·40	92·43	92·57
Carbon combined ...	·48	·78	·93	·44	·32	·47
Do. uncombined ...	2·83	2·43	2·34	2·78	3·43	2·89
Silicon	2·31	2·72	2·57	3·71	1·70	1·76
Manganese	·576	tr.	·31	·42	·30	·44
Aluminium	tr.	—	—	—	—	—
Calcium	—	—	—	—	·05	·03
Magnesium	—	—	—	—	·01	·01
Titanium	—	—	—	·20	·56	·51
Sulphur	·04	·25	tr.	·16	·13	·12
Phosphorus	·30	·30	·30	1·20	1·24	1·29
	99·566	99·16	100·58	101·31	100·17	100·09

	Clarence. No. 3 Pig.	Clarence. No. 3 Pig.	Clarence. No. 3 Pig.	Clarence. No. 4 Pig.	Clarence. No. 4 Pig.	Tees. No. 4 Pig.
Iron	93·96	93·66	92·35	94·64	91·55	93·84
Carbon combined ...	·43	·28	1·24	·26	1·26	·22
Do. uncombined ...	2·67	3·13	·68	2·45	1·06	2·72
Silicon	2·70	·88	1·80	1·87	1·84	2·16
Manganese	·52	·37	·81	·93	1·06	·50
Aluminium	—	—	·36	—	·27	—
Calcium	—	·30	·93	—	·44	·45
Magnesium	—	·02	·24	—	·15	tr.
Titanium	·25	·14	—	—	—	·09
Sulphur	·10	·17	·04	tr.	·80	·26
Phosphorus	·72	1·23	1·55	1·00	1·57	·83
	101·35	100·18	100·00	101·15	100·00	101·07
			Crowder.		Crowder.	

	Clarence. Mottled.	Clarence. White.	Clarence. White.
Iron	93·59	97·30	97·036
Carbon combined ...	·85	·90	·788
Do. uncombined ...	2·70	1·06	
Silicon	·56	·11	·40
Manganese	·79	·11	—
Aluminium	—	—	—
Calcium	·26	·15	—
Magnesium	·07	·06	—
Titanium	—	—	—
Sulphur	·35	·96	·312
Phosphorus	1·05	·26	1·434
	100·22	100·91	100·00

From the following summary of some of the experiments on iron, undertaken by the War Department, an idea of the important question of relative strength may be gained. It is only fair to add that these trials were made soon after the works on the Tees commenced operations, since which time the qualities of the ore and its mode of treatment are better understood.

Kind of iron.	Qual.	Sp. gr.	Breaking weight, tensile test. lbs.	Breaking weight, transverse. lbs.	Deflection.	Breaking weight, torsion. lbs.	Angle torsion.	Force required for crushing. lbs.
Whitehaven—Hematite Foundry..	1	7·097	14233	4644	·161	3724	7·2	52136
	3	7·214	17751	5105	·120	4182	5·8	82265
	4	7·196	17566	6100	·152	4977	4·9	82583
Butterley—Clay ironstone	1	7·141	23388	7106	·145	7346	9·3	88488
	2	7·078	18970	6077	·128	6011	7·5	74743
	3	7·126	23265	6692	·130	6940	7·5	91663
Ystalyfera—Clay do. Anthracite ...	1	7·165	25172	7848	·163	6704	12·2	87457
	2	7·157	26758	7944	·196	6176	9·6	90874
	3	7·150	24533	7228	·166	5719	8·8	88772
Blenavon................................		7·163	26766	7947	·182	5487	6·1	105202
Blenavon Cold Blast	1	7·137	25456	7493	·171	5034	9·	91897
	3	7·158	23906	7600	·191	5674	10·2	87358
Cleveland—Stockton Furnaces......	1	7·148	25810	7159	·136	5872	4·2	99526
	2	7·135	22271	6932	·134	6305	5·7	87063

From these figures it would appear that the iron from this northern locality stands very well even when contrasted with some of the best brands of the kingdom. A large founder at Middlesbro' states the Cleveland iron to be strong in the lower classes, viz. Nos. 3 and 4. A bar 2 in. × 1 in., with bearings 3 feet apart, carried 27 to 30 cwt. Under tension, bars having a sectional area of one centimetre bore 35 cwt. before fracture occurred. In melting for the foundry, the same authority states 2 to 2½ per cent. to be the loss on pig iron obtained from Cleveland stone.

At the Clarence Works the following experiments were undertaken with bars to ascertain the breaking-weights. The bars were 2 in. × 1 in., and supported on bearings 3 feet apart:—

Quality of iron in bar. No. 4. Deflection.		Breaking weight. cwt.	qr.	lbs.	
No. 1.........	·65 in.	29	2	22	
2.........	·62 „	28	2	22	
3.........	·60 „	30	0	22	
4.........	·56 „	30	0	22	
5.........	·59 „	27	2	22	
6.........	·60 „	29	0	22	
7.........	·62 „	29	0	22	
8.........	·55 „	28	2	22	
9.........	·52 „	28	2	22	
10.........	·55 „	29	2	22	
Average......	·586 „	29	0	22	
No. 4 iron 10 others	·609 „	28	0	5	
4 „ 10 „	·593 „	28	2	27	...run from No. 2 pig.
4 „ 10 „	·593 „	28	2	12	...run from No. 3 pig.
Mottled.					
No. 1.........	·058 „	31	2	22	
2.........	·054 „	29	2	22	
3.........	·048 „	27	2	22	
4.........	·041 „	26	2	22	
5.........	·046 „	27	2	22	
6.........	·048 „	29	2	22	
Average......	·049 „	28	2	3	

Effect of Manganese in the Blast Furnace.—The experiments of M. Caron in ascertaining the effect of manganese on pig iron, which he found sensibly

to reduce the amount of sulphur, led the writer to try the effect of it in the Clarence furnaces. The results, in a chemical point of view, are not devoid of interest, inasmuch as they afford some indication of the behaviour of this metal under the treatment of an iron furnace. The ore itself was poor in manganese; the composition was as follows:—

Silica	25·00
Peroxide of iron	24·30
Do. manganese	37·19
Oxide of do.	8·51
Loss by heat	5·00
	100·00

The iron produced gave by analysis for different qualities as follows:—

	No. 1 Pig.	No. 2 Pig.	No. 3 Pig.
Carbon	2·94	2·90	3·30
Silica	2·50	3·53	3·80
Manganese	1·75	2·31	2·45
Sulphur	·292	·247	·254
Phosphorus	·416	·860	·867

As far as the two last-mentioned elements are concerned, the addition of manganese in the furnace does not appear to have effected much change, but it is quite possible that the increase of this metal may, when the iron is remelted for the founder, remove a portion of the sulphur. M. Caron ascertained that this change occurred when manganese was fused with iron containing sulphur. Want of opportunity has prevented this examination from being pursued.

The slag was of the following composition while the furnace was working with the manganese ore:—

Silica	29·25
Alumina	19·25
Lime	38·25
Magnesia...	·60
Protoxide of iron	1·04
Do. manganese	8·76
Sulphur	2·16
Oxide of titanium	·75
	100·06

By calculation it was ascertained that for 100 parts of metallic manganese introduced into the furnace,

There came out in the iron	9·5
In the slag...	87·6
Leaving unaccounted for...	2·9
	100·0

These figures require a little modification, difficult to define, arising from a varying amount of manganese being found both in the iron and in the slag of furnaces using Cleveland ironstone alone.

Use of the Waste Gases.—The waste gases are employed for raising steam and heating the blast, but on the use of this mode of economizing coal there still exists a considerable diversity of opinion. Extra consumption of high-priced coke, and irregularity of working in the furnaces themselves, is not in every case a commercial equivalent for the inferior small coal saved, and labour in firing boilers, &c., avoided. In the writer's opinion there is some force in the objection; at the same time his own experience, after incurring

great expense in the necessary gas apparatus, leads him to persevere, in the hope that even the objections he admits to exist will vanish with the knowledge which time and patience alone can secure.

It is, however, reasonable to suppose, as far as a mere question of fuel is concerned, that the combustion of the carbonic oxide at the top of a furnace must heat the materials to a greater or less extent, and whatever this may amount to will be a saving *pro tanto* lower down the furnace.

To ascertain, if possible, what amount of heat was really imparted to the contents of a blast-furnace by the combustion of the carbonic oxide at the top, an examination has been made within the last few days of two furnaces at the Clarence Works, one open-topped, and the other close-topped. At the former the gases were burnt, and from the latter they were conducted away unconsumed. Both furnaces were of the same construction, and both were using materials similar in quantity and quality, and producing the same kind of iron. In both instances the temperature was taken 8 feet below the charging plates. At the close-topped furnace the following result was obtained:—

	Time of observation.	Temperature.	
	$2^h 25^m$	890° F.	
	2 31	1040	
	2 40	1040	
	3 5	1107	
	3 50	1240	
Put on 56 cwt. materials	3 20	1240	
	3 30	1299	Mean......1121° F.

Day following.

Time of observation	$3^h 20^m$	$3^h 20^m$	3^h	
Temperature	1175°	1227°	1275°	Mean temp. 1226°
Put on 76 cwt. materials	...	...	...	Temp. 1240

Day succeeding.

Time of observation	$3^h 20^m$	$3^h 30^m$	$3^h 35^m$	$3^h 55^m$	
Temperature	1305°	1282°	1282°	1415°	Mean 1321°
Put on 30 cwt. materials	$4^h 5^m$	...	...	...	Temp. 1438
„ 74 „	$4^h 20^m$	...	...	...	„ 1438

The mean of these observations indicates 1200 degrees as being the probable temperature of a close-topped furnace 8 feet below the charging plates.

An attempt was then made to ascertain the temperature of the gases at a point 8 feet below the charging plates of the open-topped furnace. One observation only was obtained, which indicated 1692 degrees.

In all these experiments the temperature was ascertained by heating a cylinder of copper of a given size, and ascertaining the effect it had on an accurately measured quantity of water. In the case of the open-topped furnace the temperature was so high that this apparatus became unmanageable, the copper getting so hot that the water was thrown violently out of the vessel containing it. Looking at the single observation obtained and subsequent appearances, the temperature of the gases in an open-topped furnace will probably be about 1800 degrees, or 600 degrees above that of the close-topped furnace, the datum line in each case being, as before stated, 8 feet below the charging plates.

Temperature of escaping Gases from Furnaces.—Scheerer gives 572° F. as the temperature of the upper zone of a blast-furnace. The writer recently

made the following examination of the temperatures of different furnaces working with close tops:—

Clarence No. 5 furnace, 48 feet high, making No. 4 iron.

	h	m			
Full	2	0	Temperature of escaping gases,		558° F.
	2	25	do.	do.	850
Put on 75 cwt. materials	2	35	do.	do.	580

Same furnace, making Nos. 2 and 3 iron.

	h	m			
Full	2	0	Temperature of escaping gases,		710° F.
	2	10	do.	do.	840
	2	20	do.	do.	940
Put on 25 cwt. materials	2	30	do.	do.	710

Walker No. 4 furnace, 42 feet high, making No. 4 iron.

	h	m			
Full	2	0	Temperature of escaping gases,		690° F.
	2	10	do.	do.	800
Introduced 33 c. materials	2	20	do.	do.	670

Middlesboro' No. 2 furnace, 42 feet high, making white iron.

	h	m			
Full	2	0	Temperature of escaping gases,		519° F.
	2	20	do.	do.	960
Put on 90 cwt. materials	2	30	do.	do.	469

The mean temperatures will be as follows:—

Clarence, making No. 4 iron	710°
Do. do. No. 2	825
The mean temperature of the tube conveying the gas from four furnaces was	808
Walker, making No. 4 iron	740
Middlesboro', making white iron...	715

The object of these figures is to show that, taking Scheerer's statement as our guide, the whole of the furnaces alluded to are working at a loss.

It is obvious that there is an escape of heat capable of preparing an additional quantity of material for treatment in the reducing and fusing zones of the furnace. The obvious method of making this heat available is by increasing the height of the furnace itself. This, however, has its limit, varying probably with the nature and size of the materials used. If, for example, the fuel is easily crushed, or the "mine" is small, or easily rendered so, then the altitude of the column containing it must not be above that which will permit the blast to enter freely and preserve, as far as possible, an equal temperature over every horizontal section or zone of the materials.

It is more than probable that the limits of extreme height have been already reached by experience in other localities, the ironmaster there being guided by the peculiar characteristics of his own minerals.

The iron-furnaces in Cleveland work under a totally different set of circumstances from those of Staffordshire, for instance, where the coke is friable and the "mine" small. Our coke is endowed with great hardness and capability of resisting pressure; and our ironstone, worked in great blocks, is sufficiently large to permit a free passage of air through a much higher column than otherwise would be the case.

Messrs. Bolckow and Vaughan have actually put this to the test of practical proof by erecting a furnace 75 feet high. Upon one occasion, in making No. 4 iron, the gases were escaping at a temperature of 467° just after

charging, and 665° when ready for its charge, or a mean of 517°; the reduction of something like 200° being due, no doubt, to the increased burden which this higher furnace was actually carrying.

Economy of fuel in the blast-furnace is of twofold importance: first, from its direct action in reducing the cost of making iron; and secondly, as the superiority of quality possessed by charcoal iron over that smelted by pit coal consists, in all probability, in the greater amount of impurity contained in the latter description of fuel, it obviously becomes a matter of consideration to employ as small a quantity of coke as possible, so as to diminish the weight of foreign matter introduced into the furnace. Hence any system interfering with these conditions requires close and careful watching on the part of the ironmaster.

Magnetic Ironstone of Rosedale Abbey.—Hitherto our observations have been confined chiefly to describing the natural and metallurgical features of the Main bed of ironstone in Cleveland; but as there are some matters of interest connected with the Top Seam, a short notice of it here may not be out of place.

This seam of the Lias formation (which is either the Top seam, or very near its geological position) has been wrought in two or three places, but by far the most important workings are the mines at Rosedale Abbey. The samples 1 and 2 are analyses of the Rosedale Abbey ironstone. No. 3 is the Top seam from Ingleby.

	No. 1. Blackstone.	No. 2. Bluestone.	No. 3. Ingleby.
Oxide of iron	64·90	{ 33·85 Fe O 32·67 $Fe^2 O^3$	41·14 Fe O 7·07 $Fe^2 O^3$
Do. manganese ...	—	·69	·94
Alumina	9·25	3·15	4·71
Lime	3·53	2·86	3·32
Magnesia	·99	—	3·34
Potash	—	trace	·20
Carbonic acid	—	10·36	26·00
Silica	5·70	6·95	7·37
Loss by heat	16·15	1·59	—
Sulphur	—	·03	·08
Phosphoric acid	—	1·41	1·36
Carbonaceous	—	·84	·38
Water	—	3·76	3·86
	100·52	98·16	99·77
Authorities............	W. Crowder	J. Pattinson.	Clarence Laboratory.
Metallic iron	45·43	49·20	36·95

The Rosedale stone is chiefly smelted at Ferry Hill furnaces, and to some extent as a mixture at other works. In quality the iron is much like that which is obtained from the main beds of ironstone.

The Ingleby stone is a portion of the Top seam, and, being thin and expensive to work, is now abandoned. A few hundred tons were smelted without admixture at the Clarence Works. The content of iron was verified as being superior to the ordinary Cleveland main seam, but the metal in quality did not differ from the usual make of the district.

Weardale Ores.—The Weardale ores, from the quality of iron produced by their use, require some separate notice. They are found in the veins of the mountain limestone, either as sparry or spathose carbonates, or as hydrated peroxides; the latter, no doubt, resulting from the joint effects of atmospheric and aqueous action on the former. The following information, communicated by Mr. Attwood, shows the composition of both varieties:—

	Spathose. By Dr. Percy.	Hydrated Peroxide. Dr. Percy.
Protoxide of iron	49·77	—
Peroxide of iron	·81	71·11
Protoxide of manganese	1·93	6·60
Lime	3·96	·56
Magnesia	2·83	1·90
Alumina	—	·40
Carbonic acid...	37·20	·13
Sulphur	0·04	—
Phosphoric acid	trace	·22
Water	0·30	12·40
Insoluble residue	3·12	6·32 { Si 4·0, Al 1·97
Protoxide of copper	—	trace
	99·96	99·64
Metallic iron	38·95	49·78

Dr. Richardson gives the following as the composition of a specimen of Weardale spathose ore :—

Iron	44·73
Lime and magnesia	3·95
Silica	·95
Loss by heat	35·50

The character of the iron produced from the above ores is of a marked kind, highly crystalline, and affording bar iron of a very excellent quality. Recently Mr. Attwood has succeeded, he states, by a plan of his own, in obtaining very good steel from the iron.

The composition of a description of iron coming so near in its properties to that of charcoal iron, as it does, is of sufficient interest to justify attention being drawn to it. The following table shows analyses of both foreign and Weardale iron :—

	No. 1. German. Spiegel Eisen.	2. German. Spiegel Eisen.	3. Swedish.	4. Weardale.	5. Weardale.	6. Weardale. White Spiegel.
Iron	82·11	98·655	95·27	93·01	99·510	96·775
Carbon	4·77	·210	4·02	4·10	·065	2·092
Silicon	·82	1·062	·08	·23	·140	·882
Manganese	11·12	—	·10	2·37	—	·021
Sulphur	·74	trace	·30	·21	—	·229
Phosphorus	·13	trace	·05	·07	trace	—
Copper	·31	—	—	·01	—	—
	100·00	99·927	99·82	100·00	99·715	99·999
Authorities	Dr. Percy.	Mitchell and Richard.	Dr. Percy.	Dr. Percy.	Mitchell and Richard.	Washington Laboratory, by M. Brivet.

Dr. Percy afterwards having reason to think the proportion of sulphur, as given in his analysis, was too high, repeated the examination, and found it only ·03 per cent. in Weardale Spiegel Eisen. The slag from the furnace where the specimen No. 5 was made contained—

Silica	36·80
Alumina, with a little oxide of iron and of manganese	13·80
Lime	46·00
Magnesia	2·54
Soda and potash, estimated as the difference	·86
	100·00

The coke used at the Weardale Company's furnaces is that from the bottom of our coal series, and which, as a rule here, as in some other coal-fields, appears the best adapted for iron-smelting, owing no doubt to freedom from sulphur. The subject is of interest, as showing that the results obtained by the use of charcoal abroad can be very closely imitated when suitable ores, and mineral coal of great purity is the fuel employed.

Cumberland Hematite.—The rich hematites of the Whitehaven district approach in some cases to nearly a pure peroxide of iron.

The following indicates their composition:—

	Cleator.	Cleator.
Peroxide of iron	90·58	95·16
Protoxide of manganese	·10	·24
Silica	7·05	5·66
Alumina	1·43	·06
Lime	·71	·07
Magnesia	·06	—
Sulphur	·03	trace
Phosphoric acid	trace	trace
	99·96	101·19
	School of Mines.	
Metallic iron	63·25	66·61

The following analysis shows the composition of iron from the Cleator furnaces:—

Iron	93·94
Carbon	4·18
Silicon	1·92
Manganese	·02
Calcium	·12
Magnesium	·06
Sulphur	·05
Phosphorus	·08
Authority, Clarence Laboratory.	100·37

This ore and that from Ulverstone are brought to some extent to the east coast for admixture with the Cleveland stone.

Ironstones from Ridsdale and Hareshaw (Mountain Limestone), and from Consett, near Shotley Bridge (Coal Formation).—These ironstones having been incidentally mentioned, the following analyses, by Dr. Richardson, may be of interest:—

	Ridsdale.	Hareshaw.	Consett, Shotley Bridge.
Iron	34·86	36·51	36·68
Lime and magnesia ...	9·00	11·90	4·65
Clay	14·00	7·15	15·05
Loss by heat	31·02	34·07	31·91

In each case no doubt the stone was a perfectly clean sample, quite free from adhering shale, which will account for the difference of metal between the analyses and the actual yield in the furnace, as formerly stated.

Statistics of the Pig Iron Manufacture in connexion with the Newcastle and Durham Coal-field.—The following figures, extracted from the statistical returns of the Geological Survey, afford probably the readiest mode of imparting a correct idea of the extent and rate of development of the iron-mines now under consideration.

In September 1850 the first ton of stone was worked from Eston Hill

for trial at Witton Park Works. Previous to this the valley of the Esk, and, to a small extent, the coast, furnished the produce of the Lias beds. Subsequently the quantity raised on the coast was increased a little, in consequence of the seam near Skinningrove being recognized as containing more iron.

	Esk Valley. Tons.	Coast. Tons.	Cleveland Hills. Tons.	Total tons.
1855	55,000	50,000	865,300	970,300
1856	48,000	57,164	1,141,448	1,246,612
1857	Not properly separated after this; but most of the increase may be set down as being the produce of the Cleveland Hills.			1,414,155
1858				1,367,395
1859				1,520,342
1860				1,471,319
1861				1,242,514*
1862	25,000	98,900	1,566,066	1,689,966

CUMBERLAND ORE.

	Smelted at Newcastle or Middlesbro'.	Smelted in Cumberland.	Exported to other places.	Total tons.
1854	46,785	24,000 estimated	261,257	332,042
1855	37,192	24,106	139,490	200,788
1856	41,450	39,617	168,080	278,147
1857	44,489	56,511	222,812	323,812
1858	57,040	67,248	207,254	331,542
1859	77,200	79,152	243,954	400,306
1860	81,240	128,149	257,462	466,851
1861	65,555	117,654	288,885	472,094
1862	55,838	119,285	357,997	533,120

	Weardale. Brown Hematites and Carbonates. Tons.	Newcastle. Claystone. Tons.	Cumberland. Alston. Tons.
1858	—	1,084	17,094
1859	—	—	1,871
1860	—	—	—
†1861	91,000	—	—
1862	124,750	—	820

A very large quantity of hematite is obtained from the neighbourhood of Ulverstone, a portion of which is smelted with coke from the Durham coal-field, while some of the ore itself is brought to mix with the Cleveland iron-stone. The following figures indicate the importance of the iron-trade of Ulverstone:—

	Carried to Newcastle or Middlesbro'.	Smelted at Ulverstone.	Exported to other places.	Total tons.
1861	11,838 tons	118,759 tons	388,583 tons	519,180
1862	3,548 „	167,634 „	388,209 „	559,391

The following statement gives at one view the number of furnaces on the east coast existing previous to the recent extension of the iron-trade in connexion with the Cleveland ironstone worked from the neighbourhood of Middlesbro', with other particulars of interest connected with its present condition and future prospects:—

* The Government returns are 111,253 tons short of the actual weight this year.
† The Government returns are incorrect, only giving 10,750 tons for 1861.

Name of Work.	Owners.	Furnaces previous to A.D. 1850.	Furnaces existing 1st Sept. 1863.	Building or projected 1st Sept. 1863.	Furnaces in Blast 1st Sept. 1863.
Lemington	Tyne Iron Company	2	2	—	1
Birtley	Birtley Iron Company	2	3	—	3
Wylam	Bell Brothers	1	1	—	1
Walker	Losh, Wilson, and Bell	2	5	—	2
Ridsdale	Ridsdale Iron Company	2	dismantled	—	0
Hareshaw	Hareshaw Iron Company	3	dismantled	—	0
Consett	Derwent Iron Company	14	14	—	6
Towlaw & Stanhope	Weardale Iron Company	6	6	—	4
Bedlington	Longridge and Co.	2	2	—	0
Witton Park	Bolckow and Vaughan	4	4	—	4
Middlesbro'	Bolckow and Vaughan	—	3	—	3
Eston	Bolckow and Vaughan	—	9	—	9
Clarence	Bell Brothers	—	6	2	5
Tees	Gilkes, Wilson, and Co.	—	5	—	4
Ormesby	Cochrane and Co.	—	4	—	4
Claylane	Elwin, Malcolm, and Co.	—	3	3	3
South Bank	Elwin, Malcolm, and Co.	—	3	3	3
Stockton	Holdsworth and Co.	—	3	—	3
Norton	Warner, Lucas, and Barrett	—	3	—	3
Tees Side	Hopkins and Co.	—	2	—	2
Thornaby	Whitwell and Co.	—	3	—	3
Normanby	Jones, Dunning, and Co.	—	2	—	2
South Durham	South Durham Iron Company	—	3	—	3
Felling, River Tyne	Pattinson & Co. and Bell Bros	—	2	—	0
Jarrow do.	Palmer and Co.	—	4	—	3
Wallsend do.	Palmer and Co.	—	2	—	0
Bradley	Richardson and Co.	—	4	—	0
Washington	Washington Chemical Company	—	1	—	0
Wear	Bells, Hawks, and Co.	—	1	—	1
Ferryhill	James Morrison	—	3	—	3
Seaham	Marchioness of Londonderry	—	2	—	2
Hinderwell	Hinderwell Iron Company	—	1	—	1
Haltwhistle	...	—	1	—	0
Brinkburn	...	—	1	—	0
Beckhole	Bagnall and Co.	—	0	2	0
Newport	B. Samuelson	—	0	3	0
Eskdale Side	...	—	0	2	0
Glazedale End	...	—	0	2	0
		38	108	17	78

The furnaces working hematite ore on the west coast are as follows, taken from the Geological Survey:—

		Furnaces built.	Furnaces in Blast.
1861.—	Cumberland	13	8
	Lancashire	12	10
1862.—	Cumberland	13	7
	Lancashire	14	11

According to the same authority, the following figures embrace an account of the production of pig iron from the furnaces alluded to in this paper:—

	1860. Tons.	1861. Tons.	1862. Tons.
Northumberland, using chiefly Cleveland stone	69,093	73,260	46,586
Durham, using chiefly Cleveland stone	340,921	312,030	337,218
North Riding of Yorkshire (Cleveland)	248,665	234,656	283,398
	658,679	629,946	667,202
Cumberland	87,950	55,165	103,455
Lancashire	81,250	109,377	138,563

Malleable Iron.—Malleable iron was, of course, the description of metal

produced by all those bloomeries mentioned in a previous section of this paper, as is indicated by the heaps of scoriæ found near Roman stations, monastic establishments, and other places. Coming down to more recent times, it is obvious that in a country where, comparatively speaking, there would be a considerable consumption of wrought iron, there was necessarily thrown into the market a corresponding quantity of old or scrap iron. With cheap fuel and water-power in sufficient quantity to drive small hammers, forges were erected at various suitable localities, such as Swalwell, by Crowley and Co.; Beamish and Lumley, by Hawks; Bedlington, and at various other places. It is needless to say the weight of metal so manufactured was small. The next stage in the manufacture of malleable iron was the erection of slitting-mills in different places commanding water-power; but when or where first established the writer can scarcely determine. By the kindness of Mr. Stephen Hawks, who has searched through the books at the Gateshead Iron Works, he has ascertained that the slit-rods used there in 1772 appeared to be all brought from London, and probably were manufactured in Wales or the Midland Counties*. Slit-rods were first made in this neighbourhood from hammered bars; indeed, the writer was informed by the late William Losh, one of the founders of the firm of Losh, Wilson, and Bell, that he erected a slitting-mill near Newcastle, and the iron he used was bars brought from Sweden. This would probably be about the year 1800. Cort patented the rolling of bar iron in the year 1783, and Mr. Stephen Hawks, in an old letter-book of 1799, finds Mr. William Hawks writing, "We will certainly roll the iron to the dimensions you mention;" so that probably rolling-mills were introduced in the neighbourhood of Newcastle a very short time after their invention by Cort. In the year 1800, according to information received from Mr. G. C. Atkinson, a small mill was erected at Lemington.

Mr. William Longridge states that his father commenced the Bedlington works in 1809, the river Blyth supplying the motive power. At that time a plate of 150 to 200 lbs. was considered, he observes, something wonderful to produce. It was here that, in 1820, they rolled the first malleable iron rails, an invention of Mr. Birkenshaw.

In 1827, Messrs. Losh, Wilson, and Bell erected what at that time was considered in the North a powerful mill, at Walker, capable of rolling 80 to 100 tons of bars a week. Here, as at all the other works, old scrap iron, or common Welsh bars, cut up for re-rolling, were the raw materials used. This firm led the way in extending the operation to the "puddling" of pig iron, a process adopted by them in the year 1833.

The rapid progress in Scotland of the manufacture of pig iron from black-band by means of the hot blast, and the cheapness of coal on the Tyne, induced Losh, Wilson, and Bell to increase their rolling power. A second mill was erected in 1838, where rails of the largest dimensions, and tyre-bars for the wrought-iron wheels, invented by Mr. Losh, were manufactured.

The old house of Hawks and Company soon after added largely to their means of producing wrought iron. In this they were speedily followed by the Derwent Iron Company, who erected immense rolling-mills at Consett, near Shotley Bridge, and increased largely the capabilities of the Bishop-wearmouth Iron Works, which they had previously purchased. There would

* From information communicated by Mr. S. Hurrell, it would appear that, in all probability, the slit-rods imported to the Gateshead Works were from the mills of a Mr. Reynolds, in Shropshire.

be in the district, previous to 1850, about 300 puddling-furnaces, capable of turning out above 150,000 tons of finished iron per annum.

The following list, compiled from actual returns, shows the number of puddling-furnaces now existing in connexion with the iron-works of the Northumberland and Durham coal-field:—

Works.	Firms.	Number of Puddling Furnaces.
Walker	Messrs. Losh, Wilson, and Bell	50
Gateshead	Messrs. Hawks, Crawshay, and Sons	33
Consett	Derwent Iron Company	99
Bishopwearmouth ...	Derwent Iron Company	31
Birtley	Birtley Iron Company	6
Bedlington	Messrs. Mounsey and Dixon	14
Shotley Bridge ...	Messrs. Richardson and Son	27
Hive, Jarrow ...	Messrs. Elliot and Co.	10
Sunderland	Messrs. Tyzack and Co.	7
Britannia	G. Hopper	16
Jarrow	Messrs. Palmer and Co.	30
Tudhoe	Weardale Iron Company	64
Middlesbro'	Messrs. Bolckow and Vaughan	68
Witton Park ...	Messrs. Bolckow and Vaughan	71
Tees Side	Messrs. Hopkins and Co.	55
Albert	Messrs. Barmingham and Co.	45
Stockton	Stockton Iron Company	20
	Total	646

The united power of all these works will be equal to an annual production of 340,000 tons of finished iron, and probably the actual make during the year 1862 may have amounted to 300,000 tons.

In addition to the quantity of iron obtained by the puddling process, a considerable weight, possibly as much as 10,000 tons per annum, is manufactured from old iron imported from various parts of the kingdom.

At first a much stronger opinion existed in favour of refining pig iron previous to puddling it than is the case at the present moment. In fact, it may be said that this mode of working has been all but abandoned as more wasteful than simply puddling the pig iron direct, and indeed one manufacturer of great experience gives as the result of his observation that a sectional inch of boiler-plate had its breaking-weight actually diminished by interposing the process of refining between the pig and the puddled bar. At the new works no refineries are built, and at the older establishments the refineries are all but discontinued.

There are probably less mill and forge cinders used in the manufacture of pig iron from the lias ironstone, either for bar or other purposes, than in any other iron-district in the kingdom, and this obviously from the greater abundance and cheapness of ironstone. The extra loss in puddling and the depreciation of quality in the malleable iron are more than an equivalent for any saving in the blast-furnace which may be effected by using the forge cinders, into which the greater part of the phosphorus of the pig finds its way. It is also not improbable that the admixture of mill and forge cinders might, with the constitution of the Cleveland ores, be more detrimental to the quality of the bars than is the case in districts smelting other kinds of ironstone. At all events, our bar-iron makers seek to avoid any risk of this by its very sparing use.

Some bar-iron manufacturers prefer pig having an admixture of a little hematite in the blast-furnace, or they seek to secure the advantages resulting from the use of this class of iron by using hematite pig in the puddling-

furnaces. It is highly probable that some good attends such a course of procedure, as well from the acknowledged excellence of hematite pig as from the advantage that is generally admitted to accrue from using different varieties in the manufacture of malleable iron. The fact, too, that the tendency of the Cleveland iron is towards cold shortness, while that of the hematite is in the opposite direction, increases the probability of the soundness of these views. At the same time, by care in puddling and in the subsequent process, bar iron of a very high class of excellence can be produced from pig obtained from Cleveland ironstone alone.

Messrs. Bolckow and Vaughan have kindly furnished the writer with a series of samples which have been submitted to breaking strains, and the following are the results:—

Experiment.					Tons.	cwt.
No. 1	boiler plate $\frac{5}{8}$ thick sec.,	= 1 in. sq.,	breaking wt.,		26	10
No. 2	do.	,,	1 in.	do.	27	0
No. 3	do.	,,	1 in.	do.	25	0
No. 4	do.	,,	1 in.	do.	26	0
No. 1	bar iron	,,	1 in.	do.	25	0
No. 2	do.	,,	1 in.	do.	25	0
No. 3	do.	,,	1 in.	do.	25	10
No. 4	do.	,,	1 in.	do.	24	10
No. 5	do.	,,	1 in.	do.	24	10
No. 6	do.	,,	1 in.	do.	24	0
No. 7	do.	,,	1 in.	do.	25	0
No. 8	do.	,,	1 in.	do.	25	0
No. 9	do.	,,	1 in.	do.	25	0
No. 10	do.	,,	1 in.	do.	25	0
No. 11	do.	,,	1 in.	do.	25	0
No. 12	do.	,,	1 in.	do.	25	10

No. 13 do. submitted for 60 hours to a strain of 22 tons, during which time the elongation was $\frac{3}{8}$ths of an inch.

The quality of both the plates and bars tested in these experiments was No. 3 of extra quality.

Not a bad estimate of the inherent excellence of any pig iron may be formed from the quality of bars it is capable of producing and from the loss of weight incurred in the process of puddling. Within the last few days the writer has received from the manager of one of the largest bar-iron works in Scotland a return of the quantity of Scotch pig iron required to make one ton of puddled bar. He gives $22\frac{1}{2}$ cwt. of pig for one ton of refined metal; $21\frac{1}{2}$ cwt. $\frac{3}{4}$ths refined and $\frac{1}{4}$th pig to a ton of puddled iron, which is equal to $23\frac{1}{2}$ cwt. of pig per ton of puddled iron. When the pig is not refined but puddled direct, $23\frac{1}{4}$ cwt. are consumed for one ton of puddled iron. These figures, from personal experience of some years, the writer considers to indicate as good a yield as the Scotch iron is capable of affording. From two separate works using pig iron made from Cleveland ironstone the following returns have been furnished: from one, the produce for the whole of 1862 was 22 cwts. 0 qrs. 16 lbs. of pig to the ton of puddled iron, and for the first six months of 1863 it was 22 cwts. 0 qrs. 17 lbs. at the same work. The second establishment gives for the year 1862, 22 cwts. 0 qrs. 16 lbs. of No. 4 iron to the ton of puddled bar. The loss, therefore, on iron produced from Cleveland ironstone is only about 66 per cent. of that when using Scotch iron, and the quality of the former is such that the preliminary process of refining, as has been already stated, is all but entirely dispensed with.

Many of the forges being, under the circumstances just enumerated, of recent construction, embrace all the latest improvements. Very powerful steam-hammers forge down the puddled balls so rapidly into blooms or slabs,

that two of these are frequently taken simultaneously to the puddling-mill and rolled out by "doubling" into a single bar, of dimensions varying with the subsequent destination of the product.

In the puddling-furnaces different materials are employed in different localities for protecting the iron bottoms. In some places the plastic hematite from Lancashire is the substance used; in others limestone is preferred. In most cases, however, "bulldog," *i. e.* calcined mill-furnace scoriæ, ground and mixed frequently with a small quantity of red ore, is found a good covering. This substance is capable of resisting the corroding action of puddling pig, which is more rapid than that of refined metal, or a mixture of refined metal and pig.

The qualities of pig iron used in the puddling-furnaces vary with circumstances; for a fibrous quality of bar, No. 4 forge pig gives very satisfactory results. A considerable quantity also of white and mottled iron is worked up in our forges.

Finishing mills of great power have been constructed, capable of rolling rails, bars, angle and girder iron of any section, and of the greatest lengths produced in this branch of manufacture. Sheets of all kinds and plates of the largest dimensions, short of the huge masses of iron now applied to our ironclads, are also turned out, of excellent quality.

Supposing the make of pig iron in the district more immediately connected with the Cleveland ironstone field to have been 667,000 tons, it will probably have been disposed of as follows:—

	Tons.
For foundry purposes in the neighbourhood, say	150,000
For malleable iron	400,000
Exported elsewhere	117,000
Total	667,000
In addition to the ironstone and hematite consumed on the east coast, amounting, as we have already seen, to about	1,870,000
There will have been used in pig and bar iron-works and foundries of coal, say	2,900,000
Limestone at the blast-furnaces	500,000
Total weight of materials	5,270,000

The capital employed in mines, blast-furnaces, and malleable iron-works will be from two to three millions sterling.

The annual amount of wages for miners, furnace-men, and workmen engaged in the mills, forges, &c., say	£1,750,000
The dues paid to the railways for carriage on minerals and on iron will not be far short of	500,000

The activity imparted to our local iron-trade by the recent discovery of the Cleveland bed of stone, near Middlesbro', has few, if any, parallels in the commercial history of the kingdom. Fifty years ago Staffordshire and Wales had reached great eminence as iron-producing districts. Their powers sufficed at that time to supply the chief requirements of our commerce. Gradually, as this demand increased, their means of production extended, until Neilson's discovery of the hot-blast enabled the Scotch ironmasters, five-and-thirty years ago, to bring their rich black-band into competition with the clay ironstone and hematite ores of England.

Enormous as are the quantities of iron produced by the works of the localities just enumerated, it must be remembered that their present condition was the growth of a considerable period of time. Ten years, on the other

hand, sufficed to place the iron-trade connected with the Cleveland bed of ore in its present remarkably conspicuous position.

The Middlesbro' ironstone was opened out in the latter part of 1850, and in the year 1860 the following numbers indicate the weight of pig iron smelted in the districts quoted for the sake of comparison:—

Northumberland, Durham, and the North Riding of York ...	658,679 tons.
North and South Staffordshire	616,450 „
South Wales	969,025 „
Scotland (the whole of)	937,000 „

The figures are from the Geological Survey.

This rapid rate of increase in our local trade has been maintained without the exercise of any influence of a speculative character. New markets had to be sought, increased sources of consumption had to be organized in our own vicinity, and some prejudices had to be overcome before the new brands of this additional iron district were fairly accepted as an important contribution to the metallurgical industry of the kingdom. Now that this much has been honestly and completely accomplished, we may fairly look for a great extension of those local branches of manufacture in which iron plays an important part. With our cheap fuel, magnificent and improving harbours, and enormous commerce, it is only reasonable to suppose that rolling-mills, engineering establishments, iron-ship building, and many other similar undertakings will find a place among us, and assist in maintaining for the North of England a very honourable rank in those industrial communities which contribute so largely to the welfare and prosperity of the British empire.

On the Manufacture of Steel in the Northern District. *By* THOMAS SPENCER, *M.I.M.E.*

THE history of the manufacture of steel in this locality commences at a very early period; for we find that, probably three hundred years ago, a colony of Germans settled at a place on the river Derwent, within a few miles of this town, and, according to tradition, there established this branch of local industry, where they also attained some celebrity as manufacturers of swords and edge tools. The names of these immigrants, who, it is stated, took refuge in this country that they might enjoy religious liberty, were Ole, Mohl, Vooz, &c., &c., and some of whose descendants still reside in the village where their ancestors originally settled, the names being now Anglicized to *Oley*, *Mole*, &c. The name of the village is Shotley Bridge, and in the wall of an old two-story dwelling-house, the original materials of which are hidden under a coat of "rough cast," there still exists a stone above the doorway with an inscription in bad German, to the following effect:—DES. HERREN. SEGEN MACHET. REICH. OHN. ALLE. SORG. WAN. DV. ZVGLEICH. IN. DEINEM. STAND. TREVW. VND. FLEISIG. BIST. VND. DVEST. WAS. DIR. BELOHLEN. IST. 1691, of which the following is a free translation, showing that the original importers of the steel-manufacture to this district were probably good Lutherans, who had suffered persecution for conscience' sake:—"The blessing of the Lord makes rich without care, so long as you are industrious in your vocation and do what is ordered you."

But there is a much earlier record of these German immigrants than the

above, the parish register at Ebchester Church containing the following entry, by which it will be seen that the name even then had undergone a change:—"Elliner, the daughter of Mathias Wrightson Oley, was baptized on the 17th day of June, 1628." It shows also that the grandfather of the child then baptized had probably married into a family of the name of Wrightson, at that time resident in the neighbourhood, as appears by several entries in the parish register of the period, clearly marking a third generation.

In all probability the next works of this nature established in this locality were those of Sir Ambrose Crowley, who is described as an ironmonger, and afterwards Alderman and Lord Mayor of the city of London, and who appears to have commenced a manufactory at Winlaton Mill in the year 1691. The names of Landells and Chambers are mentioned as being in this trade at an early period, after whom came Cookson, Spencer, and others, whose works are carried on at the present time.

The manufacture of steel, as at present carried on in this district, comprises the following descriptions:—Blistered, shear, spring, and cast steel, to produce which the following materials are required:—Iron, carbon in the shape of charcoal, manganese, coal, coke, fire-bricks, and fire-clay; of these the iron and manganese are imported into the district, the former, for the best qualities of steel, being brought from Sweden. The charcoal, coal, coke, fire-bricks, and fire-clay are produced in almost inexhaustible quantities, and of most excellent quality, in the immediate neighbourhood. A small proportion of the fire-clay, however, is brought from a distance for admixture with that found in the locality.

The mode of manufacture in use here is that known as the cementing or converting process, the furnaces used being large enough to contain from 10 to about 23 tons of material at one time; this material consists of selected iron, known to the manufacturer as being most suitable for the purpose for which it is ultimately intended. It is placed in the cells of the furnaces with bruised charcoal in alternate strata, the whole being covered with a vitreous material to effectually exclude the air; and heat is applied for a period of about eight or ten days, according to the degree of carbonization required. The mass is allowed to cool for several days, and the bars are then taken out in the form of blistered steel. The change that has taken place in its structure since it was placed in the converting furnace is very marked; for instead of being of a fibrous nature, it is now quite of a crystalline character, and it must be reduced or drawn out under rolls or heavy hammers to bring back to it something of its former nature. It is, however, used in the blistered state for many purposes, such as for welding into hammer faces, and for welding to iron for edge tools and for spades and shovels, although cast steel is now fast superseding its use even for these purposes. Spring steel is made by simply reducing with rolls the blistered bars; and shear steel is made by repeatedly drawing down and welding the blistered bars. This last-mentioned description is also being fast superseded since the introduction of mild welding cast steel.

The most important of what may be termed the secondary processes of this manufacture is that for producing cast steel, and it is (among the old methods of making steel) of the most recent introduction. Cast steel is different from all the other descriptions of steel in its fineness of grain, greater strength, and its homogeneity. The first steel used in this country partaking at all of the nature of this description of steel was the Indian Wootz, which was much prized by users of steel, especially by the makers of dies for coining-presses, who, it is said, paid the almost fabulous price of five

guineas per pound for it. The discovery of the English method of making cast steel is due to Benjamin Huntsman, of Attercliffe, who appears to have arrived at it by a series of experiments. He was a clockmaker, and desired to improve the quality of steel for clock springs. He was born in some part of Lincolnshire in the year 1704, and although his family are said to have been German, he must have become thoroughly Anglicized, as he was a strict Quaker. In all probability, this discovery was made before the year 1760, as it had become public previous to his death, which took place in 1776, at 72 years of age. This process was first introduced into this locality by the late firm of Messrs. Crowley, Millington, and Co., at the beginning of the present century, probably about the year 1810, who were next followed by Messrs. Spencer, of Newburn. Afterwards, Messrs. Cookson and Co. erected cast steel melting-furnaces at their works at Derwentcote; and within the last few years, Messrs. Fulthorpe and Co., of Dunston, commenced this branch of the steel-trade. Cast steel is produced by breaking the blistered steel into small pieces, and placing the same in crucibles or melting-pots capable of containing 36 to 40 lbs. weight each, two of which are placed in each melting-furnace. A plentiful supply of coke is now filled into the furnaces, and by the aid of a strong draught of air an intense white heat is obtained, and kept up for three or four hours, according to the nature of the steel required. When it is ascertained that the steel is perfectly melted, the crucibles are taken out and their contents poured into iron moulds conveniently placed near, and left to stand until in a cool enough state to be taken out as cast-steel ingots. These ingots are afterwards reheated, and hammered or rolled, or it may be both hammered and rolled, according to the description of article for which it is intended to be used. To produce large ingots, a number of crucibles, containing liquid steel, are brought out of the furnaces, quickly following each other, and a continuous stream is kept flowing into the mould. There is scarcely a limit to the size of ingot that may be made in this way, as was evidenced by the monster block of steel exhibited by Krupp, of Essen, at the International Exhibition in London last year; but great risks are run of getting an unsound ingot, as the least delay in getting out every crucible of steel in perfect order might cause a cessation of the stream, and thus make an unsound casting. In the year 1839 a great improvement was made in cast steel by Josiah Heath, by the introduction of manganese.

Having described the various processes that the several different kinds of steel undergo in its manufacture, it may be useful to notice some of the new methods that have been tried in the neighbourhood.

The method of making steel by the cementing or converting process, as already described, may be called the indirect method, because the object of the process is to deprive, in the first instance, the pig iron of the whole of its carbon, making the product as nearly as possible a pure malleable iron, and afterwards imparting to it again the necessary quantity of carbon to make it into steel. The new methods seem to aim, for the most part, at making steel by a direct process, without depriving the pig iron of the whole of its carbon, and without reducing it into a malleable iron condition. This is effected by extracting a large portion of carbon, but taking care to leave in a sufficient quantity to make steel, the object being to save the great waste of metal attending the puddling of iron, as well as the actual cost of that process. Of these last methods the Uchatius process is one that was extensively experimented on a few years ago at the Newburn Steel Works, and the following is a short description of the manner in which the process was carried on.

Pig iron, of a first-class quality, was melted in a reverberatory furnace, and run into a tank filled with cold water, where it was reduced into granules; this granulated cast iron was mixed with pulverized oxide of iron and some alkaline earths, and the whole put into the ordinary steel melting-crucibles, and then placed in the furnaces, to which heat was applied in the usual way until it was brought into a fluid state. By this method it was thought that the degree of hardness of the steel was capable of being regulated by the size of the granules and by the quantity of oxides used; but after a great number of experiments, at a cost of little under a thousand pounds, on attempting to work it in large quantities, it was found that the product was so uncertain in the qualities necessary to good steel, that the process was altogether abandoned. This irregularity of the produce was probably caused by the uncertain quantity of carbon in the pig iron used.

A method of making "puddled" steel has been tried in this locality, but without success. This process was a patented invention of Riepe, a German, and consists in puddling cast iron in a furnace constructed specially for the purpose, until it is observed to be in the condition of steel. This state is found to exist when a particular form of bubble appears on the face of the metal.

The Bessemer process of making steel has also been introduced into the district, at Tudhoe, near Ferryhill, but with what success the writer is not able to say. The operation, as is generally known, consists of blowing atmospheric air through a mass of melted cast iron until the carbon and the whole of the impurities of the iron are burnt out of it. This process was so ably described by Mr. Bessemer himself, at the Meeting of the British Association at Cheltenham, that it is unnecessary to give a detailed description of it here; but it may be mentioned that he commenced by extracting only a portion of the carbon, intending to leave a sufficient quantity to produce steel, but the difficulty of adjusting the exact amount finally led him to extract the whole, and afterwards restore the exact quantity requisite by adding a measured amount of highly carbonized cast iron. Experiments in making cast steel from the Taranaki sand from New Zealand, and also from another similar sand from the coast of Italy, have been tried at Newburn, with a result of getting an excellent quality of steel; but, although yielding about 51 per cent. of metal, the cost of its production, without including anything for the sand, was so great, that it would not answer commercially. It may be mentioned that this description of metallic sand appears to possess the remarkable property of not becoming oxidized when kept in a moist condition; and the writer would call the special attention of chemists and metallurgists to the fact, with the view of arriving at (what would be an invaluable discovery) the production of iron or steel that would not be subject to the destroying action of the oxygen of the atmosphere.

The articles manufactured from steel in this locality are very numerous: amongst which may be mentioned railway axles, tyres and springs, piston-rods, motion-bars, and files for engineers' use, rings for Blakeley guns, shot, &c.; the great bulk of tonnage being railway-springs of various kinds—buffing, bearing, and traction, in the laminated form, as well as the volute spring originally made in this country at Newburn, and of which there have been many hundreds of thousands made within the last few years. The rings supplied for guns made in this district have been pronounced by the consumers superior to any others. A firm, in this locality, has been appointed makers of springs for Mr. W. Bridges Adams's patent for the application of circular springs between the tyre and the frame-wheel for all kinds of rolling

stock on railways, and it is stated that springs applied in this manner effect an increased durability in Staffordshire tyres of 50 per cent. over Krupp's cast-steel tyres without the springs.

The estimated annual value of the steel manufactures of the district is about £100,000, giving employment, at the present time, to about 300 persons, and consuming annually about 15,000 tons of coals. There are in the district nine converting furnaces and fifty-two cast-steel melting-furnaces. The following is a list of the firms possessing those furnaces:—Messrs. John Spencer and Sons, Newburn, six converting and thirty-six melting-furnaces; Messrs. Cookson and Co., Derwentcote, one converting and six melting-furnaces; Messrs. Faweus and Co., Swalwell, two converting and six melting-furnaces; Messrs. Fulthorpe and Co., Dunston, six melting-furnaces.

As far as can be ascertained, it would appear that the number of persons employed in this trade in 1838 would be from seventy to eighty, and the weight of steel produced annually at that time would be about one-ninth the quantity now produced. The prices of steel range from about £18 to £112 per ton, according to the description, the quantity, and the size.

This district is highly favourable for the development of the manufacture of steel of the best quality, owing to the facility and cheapness with which a supply of iron can be obtained from Sweden—freights frequently being as low as 3*s.* 6*d.* per ton—and also owing to an abundant supply of cheap fuel and labour in the neighbourhood. The business requires, however, the most vigilant attention of thoroughly practical and experienced persons in its management to attain any considerable amount of success.

Report on the Theory of Numbers.—Part V. *By* H. J. Stephen Smith, *M.A., F.R.S., Savilian Professor of Geometry in the University of Oxford.*

120. *Geometrical Representation of Forms of a Negative Determinant.*—Before quitting the subject of binary quadratic forms, we have still to mention several investigations of great interest, relating chiefly to forms of a negative determinant. We shall first refer to the geometrical considerations which Gauss has employed to illustrate the nature of these forms *.

Let an infinite plane area be divided by two systems of parallel lines into similar and equal parallelograms. The vertices of these parallelograms we shall call nodes; and we observe that every system of nodes possesses the characteristic property, that if it be displaced without rotation in its own plane, so as to bring any one node into a position originally occupied by any other node, then every node will also occupy a position originally occupied by another node; and the system in its second position will entirely coincide with the system in its original position. From this property we infer that the system of nodes admits of an infinite number of parallelisms besides the given parallelism; *i. e.* that it may be regarded, in an infinite number of different ways, as dividing the plane area into similar and equal parallelograms. For let O and O′ be any two nodes such that no node lies on OO′ between O and O′; let P be one of those nodes which lie the nearest to the line

* See Gauss's review of Seeber's "Untersuchungen über die Eigenschaften der ternären quadratischen Formen," in the Göttingen 'Gelehrte Anzeigen' for 1831, No. 108, or in Crelle's Journal, vol. xx. p. 312; also Lejeune Dirichlet, Crelle, vol. xl. p. 209.

OO′ produced indefinitely both ways, and let PP′ be drawn parallel and equal to OO′; then P′ is a node, and OO′P′P is a parallelogram of which the vertices are nodes, and which has no other node either on its contour or in its interior; such a parallelogram we shall call an elementary parallelogram. It is then evident from the characteristic property of the system, that every elementary parallelogram supplies us with a parallelism of the system; also we can obtain an infinite number of dissimilar elementary parallelograms; for if Ox and Oy are the two lines of the given parallelism which intersect in O, and if m and n are any two integers relatively prime, the intersection of the mth parallel from Ox with the nth parallel from Oy will give a node O′ such that no node can lie on OO′ between O and O′; and, again, instead of P in the preceding construction, we may take any node lying on either of the two lines of the system which are the nearest to OO′. The areas, however, of all elementary parallelograms are equal. To prove this, we observe that if AOB is an elementary triangle (*i. e.* a triangle of which the vertices are nodes, but which has no other node either on its contour or inside it), the parallelogram OAO′B obtained by drawing parallels to any two of its sides OA and OB through the opposite vertices B and A is an elementary parallelogram. For if AO and BO are produced to A′ and B′, so that O bisects AA′ and BB′, A′ and B′ are nodes, and the triangle A′OB′ is elementary; because if there were a node x' (other than its vertices) in A′OB′, we could immediately construct a node x (other than its vertices) in AOB. But A′OB′ can be made to coincide with BO′A by a displacement without rotation; therefore BO′A is elementary as well as AOB; or the parallelogram AOBO′ is elementary. Hence, if two elementary triangles have a common base, they are certainly equal. For if through the vertex of either triangle we draw a parallel to the base, an elementary parallelogram will be contained between that parallel and the base; that is, the altitude of either triangle will be the distance of the base from the parallel nearest to the base; or the triangles will be equal. Again, let AOB, aOb, be any two elementary triangles, which we may suppose to have a common vertex; if BOa is an elementary triangle, they are each of them equal to it and to one another; if not, let x be that node contained in BOa which lies the nearest to OB, then BOx is elementary, and has the side BO in common with AOB; by proceeding in this manner we shall form a series of elementary triangles, of which the first is AOB, and the last aOB, each triangle having a side in common with that preceding it, whence AOB$=a$Ob; *i. e.* any two elementary parallelograms are equal.

We shall next show that it is always possible to find a *reduced* parallelogram, *i. e.* an elementary parallelogram, the sides of which are not greater than its diagonals. Let O be any node; A a node as near to O as any other; B a node on one of the parallels nearest to OA, and as near to O as any node on either of those parallels; complete the elementary parallelogram OAO′B; it will have the property required. Produce O′B to O″, making BO″$=$O′B; then AB$=$OO″; but by hypothesis OA $\leqq$ OB, and OB $\leqq$ OO′, OB $\leqq$ OO″; *i. e.* the sides of OAO′B are not greater than its diagonals.

Again, if OAO′B is a reduced parallelogram in which OA $\leqq$ OB, it can be proved that no node lies nearer to O than A, and that no node, out of the line OA, lies nearer to O than B; for, first, no node on the line O″BO′ lies nearer to O than B, because by hypothesis OB $\leqq$ OO′, OB $\leqq$ OO″, and because the extremity of the perpendicular drawn from O to O″O′ falls between the points of bisection of the segments O″B and BO′, or on one of those points: secondly, no node on any parallel beyond O″BO′ can lie as near to O as B,

for the limits of the angle AOB are evidently 60° and 120°; whence the perpendicular distance of OA from the parallel nearest to it but one is $\geqq OB\sqrt{3}$; *i. e.* the distance of any node on that parallel from O is $>$ OB.

If then we join any node O, first to a node A, which lies as near to O as any other node, and, secondly, to a node B, which lies as near to O as any node out of the line OA, the joining lines are adjacent sides of a reduced parallelogram; for, by what precedes, B must lie on one or other of the parallels nearest to OA.

In general, a system of nodes has but one reduced parallelism, because in general there is a pair of opposite nodes AA′ each of which is nearer to O than any other node whatever, and a second pair of opposite nodes BB′, not lying in the line AOA′, each of which is nearer to O than any node not lying in that line. Even if A and B are equidistant from O, provided only that their common distance from O is less than the distance of any other node from O, the system has but one reduced parallelism. But there are two special cases in which a nodal system admits of more than one reduced parallelism.

1. If there is one pair of opposite nodes AA′ nearer to O than any other node, and two pairs BB′, bb', equidistant from O, not lying in the line AOA′, and nearer to O than any other node not in that line, the system admits of two reduced parallelisms, having one set of parallels in common, and having their common set of parallels equally inclined to the other two sets.

2. If there are three pairs of points at the minimum distance from O, the system of nodes forms a system of equilateral triangles; and, suppressing in turn each one of the three systems of parallel lines by which these triangles are formed, we obtain the three reduced parallelisms of which the system admits.

That, in these two cases, the reduced parallelisms are such as we have described, and that, except in these two cases, there is but one reduced parallelism, may be inferred from the existence of a reduced parallelogram in every system, and from the properties which have been shown to belong to it.

To apply these results to the theory of quadratic forms, let $ax^2+2bxy+cy^2$ be a form of the negative determinant $-\Delta$; let $\cos\omega=\frac{b}{\sqrt{ac}}$, and with a pair of axes inclined to one another at an angle ω, let us construct all the points whose coordinates are integral multiples of $\sqrt{a}$ and $\sqrt{c}$ respectively; thus forming a nodal system. The expression $ax^2+2bxy+cy^2$ will then represent the square of the distance between any two nodes, the differences of whose coordinates are $x\sqrt{a}$ and $y\sqrt{b}$: and the area of an elementary parallelogram will be $\sqrt{\Delta}$. If the transformation $x=\alpha X+\beta Y$, $y=\gamma X+\delta Y$, where $\alpha\delta-\beta\gamma=\pm 1$, change $ax^2+2bxy+cy^2$ into $AX^2+2BXY+CY^2$; and if, in the same plane as before, we construct a nodal system corresponding to the latter form—the directions of rotation from the axis of X to the axis of Y, and from the axis of x to that of y, being the same—it will be found that the two systems may be made to coincide. For if we consider the point in the first system whose coordinates are $x\sqrt{a}$, $y\sqrt{c}$ as corresponding to the point in the second system whose coordinates are $X\sqrt{A}$, $Y\sqrt{C}$, the distance between any two points of the first system is equal to that between the corresponding points of the second system; therefore the two systems are identical, and are either similarly situated, *i. e.* are capable of being made to coincide by moving either of them about in their common plane, or else are symmetrically situated, *i. e.* are capable of being made to coincide after the plane of one of them has been

turned over and applied again to the plane of the other. On comparing any two corresponding triangles in the two systems, for example the triangle obtained by giving to X and Y the values (0, 0), (1, 0), (0, 1), with the triangle obtained by giving to x and y the values (0, 0), (α, γ), (β, δ), it will be seen that the two systems are similarly or symmetrically situated, according as $\alpha\delta-\beta\gamma=+1$, or $=-1$.

It thus appears that a class of quadratic forms of a negative determinant may be considered to represent a nodal system, and that each form of the class corresponds to a parallelism of the system. Conversely, to each parallelism of the system a form of the class corresponds. For let Ox, Oy be lines of any parallelism of the system, and OX, OY lines of any other parallelism, the directions of rotation from Ox to Oy and from OX to OY being the same; let also $\sqrt{a}$, $\sqrt{c}$ be the lengths of the sides of an elementary parallelogram in the first system, and $\frac{b}{\sqrt{ac}}$ the cosine of the angle between them; and let $\sqrt{A}$, $\sqrt{C}$, $\frac{B}{\sqrt{AC}}$ have the same signification with regard to the second system; then, if $(x\sqrt{a}, y\sqrt{c})$, $(X\sqrt{A}, Y\sqrt{C})$ are the coordinates of the same node P, we must have two equations of the form $x=\alpha X+\beta Y$, $y=\gamma X+\delta Y$, in which x and y are integral if X and Y are so, and *vice versâ*; hence α, β, γ, δ are integral, and $\alpha\delta-\beta\gamma=+1$; the sign of the unit being determined by the supposition we have made as to the situation of the axes with respect to one another. Also $OP^2=ax^2+2bxy+cy^2=AX^2+2BXY+CY^2$; or the two given parallelisms are represented by two properly equivalent forms.

The theorem that in every nodal system a reduced parallelism exists, has for its arithmetical expression, "In every class a form exists in which $[2b] \leq [a]$, $[2b] \leq c$." We thus obtain an independent proof of the theory of reduction of Art. 92; the geometrical signification of the special conditions in the definition of a reduced form is as follows:—If $a=c>[2b]$, the corrresponding nodal system has only one reduced parallelism; but either of the two directions in this reduced parallelism may be taken for the axis of x, consistently with the condition that the rotation from Ox to Oy should have a given direction; the condition $2b \geq 0$ implies that if the angle between the axes is not right, that direction is to be assumed for the axis of x which renders the angle between Ox and Oy acute. Similarly, if $a<c$, but $a=[2b]$, the system has two reduced parallelisms, and the condition $2b \geq 0$ distinguishes one of them from the other. If $a=[2b]=c$, the system has three reduced parallelisms, which are identical and similarly placed; the condition $2b>0$ does not distinguish between these, but only between the two modes in which any one of them can be taken.

The number of automorphics of a class may be ascertained by causing the nodal system which represents it to revolve in its own plane round one of its nodes, and examining the number of positions in which it coincides with its original position. After a revolution of 180° it will always do so; but in order that it should do so in any other position, the first and second sides of its reduced parallelogram must be equal, and must include an angle of 90° or 60°, *i. e.* the system must be one of squares or of equilateral triangles. Hence we infer (Art. 90) that there are in general but two automorphics for a form of a negative determinant, but that for the classes containing the forms x^2+y^2 and $2x^2+2xy+2y^2$ (or multiples of those forms) there are four and six respectively.

Similarly we may investigate the conditions for the ambiguity of a class. In order that a class should be ambiguous, the nodal system representing it must be symmetrically equivalent to itself. If therefore there is but one reduced parallelogram, that parallelogram must be symmetrically equivalent to itself, *i. e.* it must be either a rectangle or a rhombus. When there are two reduced parallelograms, we have seen that they are symmetrically equivalent to one another; and when there are three, they are each of them rhombs. We thus obtain the conclusion that if (a, b, c) is the reduced form of an ambiguous class, either $b=0$, or $a=c$, or $a=2b$ (Art. 94).

121. *Application of Formulæ relating to the Division of the Circle to the Theory of Quadratic Forms.*—We have already referred to the trigonometrical solutions of the equation $T^2-DU^2=1$ (Art. 96, ix.) and to the connexion existing between them, and the number of classes of quadratic forms of determinant D (Art. 104.)

If p is a prime of the form $3n+1$ or $4n+1$, the coefficients of the cubic, or biquadratic, equation of the periods depend on the values of the indeterminates in the equation $4p=x^2+3y^2$, or $p=x^2+y^2$ (Art. 43). Thus in these two cases, if, for any given value of p, we calculate the equation of the periods, we obtain, by a direct though tedious process, the values of the indeterminates in certain simple quadratic decompositions of $4p$ or p. But the theory of the division of the circle supplies a method equally direct and of more general application for the investigation of such decompositions in certain cases. The principles of this method were discovered by Gauss, who deduced from them the first of the three following theorems:—

"If $p=4n+1=x^2+y^2$,

$$x\equiv\tfrac{1}{2}\,\frac{\Pi 2n}{\Pi n\,.\,\Pi n},\ \text{mod}\ p;\quad x\equiv 1,\ \text{mod}\ 4;$$

$$y\equiv\pm\frac{\Pi 2n\,.\,\Pi 2n}{\Pi n\,.\,\Pi n},\ \text{mod}\ p."$$

(Gauss, Theor. Res. Biq. Comm. prima, art. 23.)

"If $p=3n+1$, $4p=x^2+3y^2$,

$$x\equiv-\frac{\Pi 2n}{\Pi n\,.\,\Pi n},\ \text{mod}\ p;\quad x\equiv 1,\ \text{mod}\ 3;$$

$$y\equiv 0,\ \text{mod}\ 3."$$

(Jacobi, Crelle, vol. ii. p. 69; Stern, *ib.* vol. vii. p. 104, vol. ix. p. 198, vol. xviii. p. 375; Clausen, *ib.* vol. viii. p. 140.)

"If $p=8n+1=x^2+2y^2$,

$$x\equiv\tfrac{1}{2}\,\frac{\Pi 5n}{\Pi n\,.\,\Pi 4n},\ \text{mod}\ p;\quad x\equiv 1,\ \text{mod}\ 4."$$

(Jacobi, Crelle, vol. xxx. p. 168; Stern, *ib.* vol. xxxii. p. 89.)

In all these formulæ the absolute value of x is evidently $<\frac{1}{2}p$; so that x is determined without ambiguity as the minimum residue for the modulus p of the binomial coefficient. And the combination of the two congruences satisfied by x gives rise in each case to a remarkable property of the coefficient: thus, from the two congruences satisfied by x in the first theorem, we infer that "if p is a prime of the form $4n+1$, the minimum residue of $\frac{1}{2}\frac{\Pi 2n}{\Pi n\,.\,\Pi n}$ for the modulus p is of the form $4m+1$."

To show, by an example, how these formulæ are obtained, we shall consider the last of them in particular. Resuming the notation of Art. 30, let θ be a primitive root of the equation $x^{p-1}-1=0$; and let $\theta^n=\theta^{\frac{p-1}{8}}=\omega, \theta^{2n}=\omega^2=i,$

$F(\omega) = \sum_{s=0}^{s=p-2} \omega^s x^{\gamma^s}$, x representing a root of the equation $\frac{x^p-1}{x-1}=0$, and γ a primitive root of the congruence $x^{p-1} \equiv 1, \bmod p$. Then $\psi(\omega) = \frac{F(\theta^{-n})\,F(\theta^{-4n})}{F(\theta^{-5n})}$ is an integral function of ω only (Art. 30, iii.); let $\psi(\omega) = a + b\omega + c\omega^2 + d\omega^3$. The function $\frac{F(\theta^{-n})\,F(\theta^{-4n})}{F(\theta^{-5n})}$ is not changed, if for θ^{-n} we write θ^{-3n}; therefore $\psi(\omega) = \psi(\omega^3)$; *i. e.* $(b-d)(1-i)\,\omega + 2ci = 0$, or $c=0$, $b=d$, and $\psi(\omega) = a + b(1+i)\,\omega$, $\psi(\omega^{-1}) = a + b(1-i)\,\omega^{-1}$; so that $p = \psi(\omega) \times \psi(\omega^{-1}) = a^2 + 2b^2$ (Art. 30, iv.). Again, $\psi(\gamma^n) = a + b(\gamma^n + \gamma^{3n}) \equiv -\frac{\Pi 5n}{\Pi n.\,\Pi 4n}$, mod p (Art. 30, v.), and $\psi(\gamma^{5n}) = a - b(\gamma^n + \gamma^{3n}) \equiv -\frac{\Pi 9n}{\Pi 4n\,.\,\Pi 5n}$, mod p; whence $a \equiv -\frac{1}{2}\frac{\Pi 5n}{\Pi n\,.\,\Pi 4n}$. To show that $a \equiv -1$, mod 4, we observe that by the definition of the function ψ, $\psi(\omega) = \Sigma\omega^{-y_1-4y_2}$, y_1 and y_2 representing any two numbers of the series $1, 2, \ldots p-2$, which satisfy the congruence $\gamma^{y_1} + \gamma^{y_2} \equiv 1$, mod p. Hence $a = \Sigma(-1)^{y_2+\eta_1}$, where η_1 is one of the numbers $1, 2, \ldots 2n-1$, and η_1, y_2 satisfy the congruence $\gamma^{4\eta_1} + \gamma^{y_2} \equiv 1$, mod p. Let σ be any one of the numbers $1, 2, \ldots n-1$, and let A, B be the values of γ^{y_2} corresponding to the values $n-\sigma$, $n+\sigma$ of η_1; then $A \times B \equiv (1-\gamma^{4(n-\sigma)}) \times (1-\gamma^{4(n+\sigma)}) \equiv -\gamma^{-4(n+\sigma)} \times (1-\gamma^{4(n+\sigma)})^2$, mod p; therefore $A \times B$ is a quadratic residue of p, and the values of y_2 corresponding to the values $n-\sigma$, $n+\sigma$ of η_1 are either both even or else both uneven; also, if $\eta_1 = n$, $\gamma^{y_2} \equiv 2$, mod p, and y_2 is even, because $\left(\frac{2}{p}\right) = 1$. Let k be the number of values of η_1, included in the series $1, 2, \ldots n-1$, for which $y_2 + \eta_1$ is uneven; then $a = \Sigma(-1)^{y_2+\eta_1} = 2(n-1) - 4k + (-1)^n$; *i. e.* $a \equiv -1$, mod 4.

We might also determine x in the equation $p = x^2 + 2y^2$ by the congruence $x \equiv (-1)^n \frac{1}{2}\frac{\Pi 4n}{\Pi n\,.\,\Pi 3n}$, mod p, or by the congruence $x \equiv 2^{2n} \times \frac{1}{2}\frac{\Pi 2n}{\Pi n\,.\,\Pi n}$, mod p. These determinations, which have been given by M. Stern, may either be obtained directly by considering the functions $\frac{F(\theta^{-n})\,F(\theta^{-3n})}{F(\theta^{-4n})}$, $\frac{[F(\theta^{-n})]^2}{F(\theta^{-2n})}$, or may be deduced from the formula of Jacobi. The formulæ for the determination of x in the first two theorems also admit of various modifications. It will be observed that, in the first, y is determined by a congruence as well as x. This determination is obtained by a comparison of the two congruences $1 + \frac{y^2}{x^2} \equiv 0$, mod p, $1 + (\Pi 2n)^2 \equiv 0$, mod p (the latter arising from Sir J. Wilson's theorem); with regard to it Gauss observes, "quum insuper noverimus quo signo affecta prodeat radix quadrati imparis, eo scilicet ut semper fiat formæ $4m+1$, attentione perdignum est, quod simile criterium generale respectu radicis quadrati paris hactenus inveniri non potuerit. Quale si quis inveniat et nobiscum communicet magnam de nobis gratiam feret."

These congruential determinations possess great interest, not only because direct methods of solution present themselves very rarely in the theory of numbers, but also on account of the singular connexion which they establish between certain binomial coefficients and certain quadratic decompositions of primes. Nor is it less remarkable that the properties of the resolvent function of Lagrange form the intermediate links in this connexion; although it is proper to observe that Gauss has exhibited his demonstration of the theorem relating to the equation $p=x^2+y^2$ in a form in which its connexion with the theory of the division of the circle is disguised.

Results of a more general character have been obtained by Jacobi and Cauchy. Cauchy has treated of the subject with great fulness of detail in his Memoir on the Theory of Numbers, in the 17th volume of the Memoirs of the Academy of Sciences (pp. 249–768); while Jacobi has barely indicated his method in his note on the division of the circle (Crelle, vol. xxx. p. 166); nevertheless, as in some respects it seems preferable to that employed by Cauchy, we shall endeavour to adhere to it in what follows.

Retaining the other notations which we have employed in this article, let $\dfrac{F(\theta^{-m})F(\theta^{-n})}{F(\theta^{-(m+n)})}=\psi(m, n, \theta)$ or $\psi(m, n)$, when there is no occasion to consider θ explicitly; we observe that $\psi(m, n)=\psi(n, m)$; $\psi(0, n)=\psi(m, 0)=\psi(0, 0)=-1$; also $\psi(m', n')=\psi(m, n)$, if $m'\equiv m$, mod $p-1$, $n'\equiv n$, mod $p-1$; $\psi(m, n)=(-1)^{m+1}p=(-1)^{n+1}p$, if $m+n\equiv 0$, mod $p-1$, but m and n are not $\equiv 0$, mod $p-1$. Let $m_1, m'_1, \ldots . m_1^{(\sigma)}$ be any set of $\sigma+1$ numbers, each of which satisfies the conditions $0\leqq m_1<p-1$; let $m_1+m'_1+\ldots+m_1^{(\sigma)}=n_1(p-1)+s_1$, where $0\leqq s_1<p-1$; and put $F(\theta^{-m_1})F(\theta^{-m_1'})\ldots F(\theta^{-m_1^{(\sigma)}})=\chi(\theta)F(\theta^{-s_1}.)$ Writing, for brevity,

$$\mu_1\equiv m_1,\ \mu'_1\equiv m_1+m_1',\ \mu_1''\equiv m_1+m_1'+m_1'',\ldots \bmod p-1,$$

and determining $\mu_1, \mu_1', \mu_1''\ldots$ so as to satisfy the conditions $0\leqq\mu_1<p-1$, we find $\chi(\theta)=\psi(\mu_1, m_1')\psi(\mu_1', m_1'')\ldots . \psi(\mu_1^{(\sigma-1)}, m_1^{(\sigma)})$. In this expression if $\mu_1^{(i)}+m_1^{(i+1)}>p-1$, we write for $\psi(\mu_1^{(i)}, m_1^{(i+1)})$ its equivalent $p\div\psi(p-1-\mu_1^{(i)}, p-1-m_1^{(i+1)})$; and if $\mu_1^{(i)}+m_1^{(i+1)}=p-1$, we write for $\psi(\mu_1^{(i)}, m_1^{(i+1)})$ its equivalent $(-1)^{1+m_1^{(i+1)}}p$. It is evident that the condition $\mu^{(i)}+m^{(i+1)}\geqq p-1$ will be satisfied n_1 times precisely; so that $\chi(\theta)$ assumes the form $p^{n_1}\dfrac{\Phi_1(\theta)}{\Psi_1(\theta)}$, $\Phi_1(\theta)$ and $\Psi_1(\theta)$ denoting products of factors of the form $\psi(h, h')$, in each of which $h+h'<p-1$. It will now be found that $\dfrac{\Phi_1(\gamma)}{\Psi_1(\gamma)}\equiv(-1)^{\sigma-n_1}\dfrac{\Pi s_1}{\Pi m_1\,\Pi m_1'\,\Pi m_1''\ldots}$, mod p. For (1), if $\mu_1^{(i)}+m_1^{(i+1)}<p-1$, we have $\psi(\mu_1^{(i)}, m_1^{(i+1)}, \gamma)\equiv-\dfrac{\Pi\mu_1^{(i+1)}}{\Pi\mu_1^{(i)}.\Pi m_1^{(i+1)}}$, mod p; (2) if $\mu_1^{(i)}+m_1^{(i+1)}>p-1$, we have $\dfrac{1}{\psi(p-1-\mu_1^{(i)}, p-1-m_1^{(i+1)}, \gamma)}\equiv$

$$-\frac{\Pi(p-1-\mu_1^{(i)}).\Pi(p-1-m_1^{(i+1)})}{\Pi(2p-2-\mu_1^{(i)}-m_1^{(i+1)})}\equiv\frac{\Pi\mu_1^{(i+1)}}{\Pi\mu_1^{(i)}.\Pi m_1^{(i+1)}},\ \bmod p,$$

since, by Sir J. Wilson's theorem, $\Pi(p-1-j)\equiv-\dfrac{(-1)^j}{\Pi j}$, mod p, if $j<p-1$; (3) if $\mu_1^{(i)}+m_1^{(i+1)}=p-1$, we have

$$(-1)^{1+m_1^{(i+1)}} \equiv \frac{\Pi\mu_1^{(i+1)}}{\Pi\mu_1^{(i)} . \Pi m_1^{(i+1)}}, \bmod p,$$

because $\Pi\mu_1^{(i)}\Pi m_1^{(i+1)} \equiv (-1)^{1+m_1(i+1)}$, mod p, by Sir J. Wilson's theorem, while $\Pi\mu_1^{(i+1)}=1$, since $\mu_1^{(i+1)}=0$: whence, multiplying and writing s_1 for $\mu_1^{(\sigma)}$, we obtain the congruence written above. Let r represent any term of a system of residues prime to $p-1$; let the numbers $m_r, m_r^1 \ldots m_r^{(\sigma)}$ be determined by the congruences $m_r^{(i)} \equiv m_1^{(i)} r$, mod $(p-1)$, combined with the condition $0 \leqq m_r^{(i)} < p-1$; and let $m_r + m_r' + \ldots + m_r^{(\sigma)} = n_r (p-1) + s_r$, where again $0 \leqq s_r < p-1$: we have for every value of r an equation of the form

$$\chi(\theta^r) = p^{n_r} \times \frac{\Phi_r(\theta)}{\Psi_r(\theta)}, \text{ and a congruence of the form}$$

$$\frac{\Phi_r(\gamma)}{\Psi_r(\gamma)} \equiv (-1)^{\sigma-n_r} \frac{\Pi s_r}{\Pi m_r \Pi m'_r \Pi m_r'' \ldots}, \bmod p.$$

Let $\chi(\theta) = A_0 + A_1\theta + \ldots + A_k\theta^k$, $k+1$ denoting the number of terms in a system of residues prime to $p-1$; let n_ν be the least of the numbers $n_1, \ldots n_{k+1}$, and j the exponent of the highest power of p dividing $A_0, A_1, \ldots A_k$: then shall $j = n_\nu$. For, first, if $j > n_\nu$, from the equation $\Psi_\nu(\theta)\frac{\chi(\theta^\nu)}{p^{n_\nu}} = \Phi_\nu(\theta)$, in which the coefficients of the powers of θ are integral numbers, we infer the congruence $\Psi_\nu(\gamma)\frac{\chi(\gamma^\nu)}{p^{n_\nu}} \equiv \Phi_\nu(\gamma)$, mod p; but $\frac{\chi(\gamma^\nu)}{p^{n_\nu}} \equiv 0$, mod p; therefore, $\Phi_\nu(\gamma) \equiv 0$, mod p, which is impossible. Secondly, if $j < n_\nu$, writing A_i' for $A_i \div p^j$, and observing that $\Psi_r(\gamma)$ is prime to p, for every value of r, we find

$$A_0' + A_1'\gamma^2 + A_2'\gamma^{2r} + \ldots + A_k'\gamma \quad \_\_ 0, \bmod p^{n_\nu - j},$$

for every value of r: but the determinant of this system is prime to p, therefore $A'_0 \equiv 0$, $A_1' \equiv 0$, $A'_k \equiv 0$, mod $p^{n_\nu - j}$, which is contrary to the hypothesis that $j < n_\nu$, and that p^j is the highest power of p dividing $A_0, A_1, \ldots A_k$.

The application of these results leads to the following general theorems; in the enunciations of which p is an uneven prime, and Δ a number not divisible by any square.

"If $\Delta = 4m+3$, $p = \Delta n + 1$, and if we represent by a and b numbers less than Δ and prime to Δ, respectively satisfying the equations

$$\left(\frac{a}{\Delta}\right) = 1, \left(\frac{b}{\Delta}\right) = -1, \text{ we have}$$

$$\text{(A)} \left(\begin{aligned} &4p^{\frac{\Sigma b - \Sigma a}{\Delta}} = x^2 + \Delta y^2, \\ &x \equiv -(-1)^{\frac{\Sigma b}{\Delta}} \frac{1}{\Pi_a[\Pi an]}." \end{aligned} \right.$$

"If $p = 4\Delta n + 1$, Δ being of any other linear form than $4m+3$, and if we represent by a and b numbers less than 4Δ and prime to 4Δ, respectively satisfying the equations $\left(\frac{-\Delta}{a}\right) = +1, \left(\frac{-\Delta}{b}\right) = -1$, we have

$$\text{(B)} \begin{cases} p^{\frac{\Sigma b - \Sigma a}{\Delta}} = x^2 + \Delta y^2 \\ x \equiv -(-1)^{\frac{\Sigma b}{4\Delta}} \frac{1}{2} \frac{1}{\Pi_a [\Pi an]}. \text{"} \end{cases}$$

In these formulæ the signs of summation extend to every value of a and b respectively; and in the expression $\Pi_a [\Pi an]$ the exterior sign of multiplication Π_a extends to every value of a, while the interior sign is the factorial symbol, so that $\Pi an = 1 \,.\, 2 \,.\, 3 \ldots an$. The number 3 is excluded from the first formula; the numbers 1 and 2 from the second.

It will suffice to show how the first of these two theorems is to be demonstrated. For this purpose we consider the product $\Pi F (\theta^{-an})$; taking an, $a'n$, $a''n$, . . for m_1, m_1', . . . we find $\chi(\theta) = -\Pi F(\theta^{-an})$; because (as may easily be proved) $\Sigma a \equiv 0$, mod Δ, whence $\Sigma an \equiv 0$, mod $p-1$. We shall now show that $\chi(\theta)$ is of the form $A\Sigma\theta^{an} + B\Sigma\theta^{bn}$. Actually multiplying the expressions $F(\theta^{-an})$, $F(\theta^{-a'n})$, ..., the coefficient, in the product, of any term such as $x^k \theta^{mn}$ is equal to the number N of the solutions of the simultaneous congruences

$$\gamma^y + \gamma^{y'} + \gamma^{y''} + \ldots \equiv k, \text{ mod } p, \; ay + a'y' + a''y'' + \ldots \equiv -m, \text{ mod } \Delta.$$

If r is a number prime to Δ, and satisfying the equation $\left(\frac{r}{\Delta}\right) = +1$, N will not be changed, if we write rm, ra, ra', . . . (or rather the least positive residues of those numbers, mod Δ) for m, a, a'. Hence, in $\chi(\theta)$ all powers of θ whose exponents are of the form an have the same coefficient A′, and all powers of θ whose exponents are of the form bn have the same coefficient B′. Again, consider a power of θ of which the exponent is of the form $\alpha\delta n$; δ representing a given divisor of Δ (other than 1 or Δ), and α representing any number less than $\frac{\Delta}{\delta}$, and prime to $\frac{\Delta}{\delta}$; all such powers of θ will have the same coefficient. For we can always find a number r prime to Δ, satisfying the equation $\left(\frac{r}{\Delta}\right) = 1$, and yet congruous, for the modulus $\frac{\Delta}{\delta}$, to any given number prime to $\frac{\Delta}{\delta}$; whence it follows that the number N will remain the same for all values of m included in the formula $\alpha\delta$. But a sum of the form $\Sigma_\alpha \theta^{\alpha\delta n}$ is equal to $+1$ or -1, according as the number of primes dividing $\frac{\Delta}{\delta}$ is even or uneven, because it is the sum of the primitive roots of the equation $x^{\frac{\Delta}{\delta}} = 1$. Thus, the function $\chi(\theta)$ assumes the form $A'\Sigma\theta^{an} + B'\Sigma\theta^{bn} + C'$, whence, attending to the equation $\Sigma\theta^{an} + \Sigma\theta^{bn} = (-1)^\lambda$, in which λ is the number of primes dividing Δ, we find, as has been said, $-\Pi F(\theta^{-an}) = \chi(\theta) = A\Sigma\theta^{an} + B\Sigma\theta^{bn}$. If we write θ^{-1} for θ in this equation, it becomes

$$-\Pi F(\theta^{an}) = \chi(\theta^{-1}) = A\Sigma\theta^{bn} + B\Sigma\theta^{an}, \text{ since } \left(\frac{-a}{\Delta}\right) = -1, \left(\frac{-b}{\Delta}\right) = +1.$$

Multiplying the two equations together, and observing that

$F(\theta^{-an}) F(\theta^{an}) = (-1)^{an} p = p$, because n is even, we obtain

$$4p^{\frac{1}{2}\psi_0(\Delta)} = [(-1)^\lambda (A+B) + (A-B)(\Sigma\theta^{an} - \Sigma\theta^{bn})]$$
$$\times [(-1)^\lambda (A+B) + (A-B)(\Sigma\theta^{bn} - \Sigma\theta^{an})],$$

or, since $(\Sigma\theta^{an}-\Sigma\theta^{bn})^2=-\Delta$*,

$$4p^{\frac{1}{2}\psi_0(\Delta)}=(A+B)^2+\Delta\,(A-B)^2,$$

$\psi_0\,(\Delta)$ representing the number of numbers less than Δ and prime to Δ. We have next to determine the highest power of p dividing $A+B$ and $A-B$, or, which is the same thing, A and B. By the principles indicated above, we have

$$A\Sigma\theta^{an}\ \ +B\Sigma\theta^{bn}=p^{\frac{\Sigma a}{\Delta}}\frac{\Phi_1\,(\theta)}{\Psi_1\,(\theta)},$$

$$A\Sigma\theta^{bn}\ \ +B\Sigma\theta^{an}=p^{\frac{\Sigma b}{\Delta}}\frac{\Phi_{-1}\,(\theta)}{\Psi_{-1}\,(\theta)}.$$

Writing in these equations γ for θ, and observing that the determinant $(\Sigma\gamma^{an})^2-\Sigma\,(\gamma^{bn})^2$†, as well as the four numbers $\Phi_1\,(\gamma), \Phi_{-1}\,(\gamma), \Psi_1\,(\gamma), \Psi_{-1}\,(\gamma)$, is prime to p, we infer that the exponent of the highest power of p dividing A and B is the less of the two numbers $\frac{\Sigma a}{\Delta}, \frac{\Sigma b}{\Delta}$. Of these the former is the less ‡; if therefore we write x and y for $(-1)^\lambda\,(A+B)\,p^{-\frac{\Sigma a}{\Delta}}$, and $(A-B)\,p^{-\frac{\Sigma a}{\Delta}}$ respectively, our equation becomes $4p^{\frac{\Sigma b-\Sigma a}{\Delta}}=x^2+\Delta y^2$. Also,

* See Art. 96, ix. of this Report, or the note on Art. 104.

† Since $\Sigma\theta^{an}+\Sigma\theta^{bn}=(-1)^\lambda$, we have $\Sigma\gamma^{an}+\Sigma\gamma^{bn}\equiv(-1)^\lambda$, mod p; and since $(\Sigma\theta^{an}-\Sigma\theta^{bn})^2=-\Delta$, we have $(\Sigma\gamma^{an}-\Sigma\gamma^{bn})^2\equiv-\Delta$, mod p. Thus the two factors of the determinant are each of them prime to p.

The principle that any rational equation containing only powers of θ and integral numbers may be changed into a congruence for the modulus p, if γ be written in it for θ, has already been employed in this article. Its truth is evident, if we observe that the irreducible equation satisfied by θ, if considered as a congruence for the modulus p, is satisfied by γ. This principle is of more general application than a similar one which has been already employed in Art. 51 of this Report; but its proof supposes the irreducibility of the equation of the primitive roots, which is not necessary to the proof of the principle of Art. 51.

‡ $\Sigma b-\Sigma a$ is certainly positive, because $\frac{\Sigma b-\Sigma a}{\Delta}$ is equal to the number of improperly primitive classes of the negative determinant $-\Delta$. Or (as it is desirable to avoid making use of this result here) $\Sigma b-\Sigma a$ is positive because $\frac{\pi}{\Delta\sqrt{\Delta}}(\Sigma b-\Sigma a)$ is the sum of the series $\sum_1^\infty\left(\frac{n}{\Delta}\right)\frac{1}{n}$, the summation extending to every value of n prime to Δ, and the terms being taken in their natural order. This series is positive, because the series $\sum_1^\infty\left(\frac{n}{\Delta}\right)\frac{1}{n^{1+\rho}}$, of which it is the limit, when ρ is diminished without limit, is certainly positive, being the reciprocal of the product $\Pi\left[1-\left(\frac{q}{\Delta}\right)\frac{1}{q^{1+\rho}}\right]$, in which the sign of multiplication extends to every prime q not dividing Δ, and in which every factor is positive. The series $\sum_1^\infty\left(\frac{n}{\Delta}\right)\frac{1}{n}$ is one of those summed by Dirichlet in the memoir "Recherches sur diverses applications, &c." (Crelle, vol. xxi. p. 141 *et seq.*): for the case in which Δ is a prime, he had already summed it in the memoir on the Arithmetical Progression (Memoirs of the Academy of Berlin for 1837, p. 55). Cauchy (Mémoires de l'Académie des Sciences, vol. xvii. p. 673 *et seq.*) inverts Dirichlet's process, and transforms sums of the form $\Sigma f(a)-\Sigma f(b)$ into infinite series. The transformation is effected by substituting for $f(x)$, in the

since $\frac{\Phi_1(\gamma)}{\Psi_1(\gamma)} \equiv -(-1)^{\frac{\Sigma b}{\Delta}} \frac{1}{\Pi_a[\Pi an]}$, we have

$$\mathrm{A}p^{-\frac{\Sigma a}{\Delta}}\Sigma\gamma^{an}+\mathrm{B}p^{-\frac{\Sigma a}{\Delta}}\Sigma\gamma^{bn} \equiv -(-1)^{\frac{\Sigma b}{\Delta}}\frac{1}{\Pi_a[\Pi an]}, \bmod p,$$

$$\mathrm{A}p^{-\frac{\Sigma a}{\Delta}}\Sigma\gamma^{bn}+\mathrm{B}p^{-\frac{\Sigma a}{\Delta}}\Sigma\gamma^{an} \equiv 0, \bmod p, \text{ whence by addition}$$

$$x \equiv -(-1)^{\frac{\Sigma b}{\Delta}}\frac{1}{\Pi_a[\Pi an]}, \bmod p.$$

If Δ is a prime, x also satisfies the congruence $\frac{1}{2}x \equiv 1$, mod Δ; for the sum of the coefficients in any function $\psi(m, n)$ is $\equiv -1$, mod $p-1$, and therefore mod Δ; whence the sum of coefficients in $\chi(\theta)$ which is a product of an even number of such functions is $\equiv 1$, mod Δ; because the reduction of $\chi(\theta)$ to the form $\mathrm{A}\Sigma\theta^{an}+\mathrm{B}\Sigma\theta^{bn}$ is effected only by means of the equations $\theta^{n\Delta}-1=0$, $\frac{\theta^{n\Delta}-1}{\theta^n-1}=0$; whereof the former does not alter the sum of the coefficients at all, and the latter alters them only by a multiple of Δ. Consequently $\frac{1}{2}(\Delta-1)(\mathrm{A}+\mathrm{B}) \equiv 1$, mod Δ, or, since $p^{\frac{\Sigma a}{\Delta}} \equiv 1$, mod Δ, and $(-1)^{\lambda}=-1$, $\frac{1}{2}x \equiv 1$, mod Δ.

It will be observed that if Δ is of the form $8m+7$, whether Δ is a prime or not, x and y are necessarily even in the equation (A); whence, dividing by 4, we may put the equation in the form

$$p^{\frac{\Sigma b-\Sigma a}{\Delta}} = x^2+\Delta y^2$$

$$x \equiv -(-1)^{\frac{\Sigma b}{\Delta}}\tfrac{1}{2}\frac{1}{\Pi[\Pi an]}, \bmod p.$$

Ex. Let $\Delta=7$, $p=7n+1$; the values of a are 1, 2, 4; of b, 3, 5, 6: hence $p=x^2+7y^2$, $x \equiv -\frac{1}{2}\frac{1}{\Pi n.\Pi 2n.\Pi 4n} \equiv \frac{1}{2}\frac{\Pi 3n}{\Pi n.\Pi 2n}$, mod p; also $x \equiv 1$, mod 7. (Jacobi, Crelle, vol. ii. p. 69.)

Whenever the exponent of p is 1, the formulæ (A) and (B) completely determine the value of x; when the exponent of p is 2, we can only be sure

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expression $\sum_{1}^{\Delta-1}\left(\frac{x}{\Delta}\right)f(x)=\Sigma f(a)-\Sigma f(b)$, the equivalent infinite series

$$\frac{1}{\Delta}\int_0^{\Delta} f(s)\,ds+\frac{2}{\Delta}\sum_{m=1}^{m=\infty}\int_0^{\Delta}\cos\frac{2m\varpi(x-s)}{\Delta}f(s)\,ds;$$

whence, observing that

$$\sum_{x=1}^{x=\Delta-1}\left(\frac{x}{\Delta}\right)\sin\frac{2mx\pi}{\Delta}=\left(\frac{m}{\Delta}\right)\sqrt{\Delta}, \text{ and } \sum_{m=\Delta}^{x=\Delta-1}\left(\frac{x}{\Delta}\right)\cos\frac{2mx\pi}{\Delta}=0,$$

we obtain $\frac{1}{2}\sqrt{\Delta}\left(f(a)-f(b)\right)=\sum_{m=1}^{m=8}\left(\frac{m}{\Delta}\right)\int_0^{\Delta}\sin\frac{2ms\pi}{\Delta}f(s)\,ds$; a formula from which Dirichlet's result is immediately deducible, by putting $f(x)=x$, and performing the integrations. It is a remarkable fact that the inequality $\Sigma b > \Sigma a$ has never been proved by elementary considerations, or without the use of infinite series (see the Memoir on the Arithmetical Progression, p. 57). If Δ is a prime, $\Sigma b-\Sigma a$ is certainly not zero, for $\Sigma b+\Sigma a$ is uneven (because Δ is of the form $4n+3$); but even this remark cannot be extended to the case in which Δ is composite.

that the absolute value of x is less than p, so that x is not completely determined, but is either the least positive or the least negative residue of the binomial coefficient; though in this case if Δ is a prime of the form $4n+3$, the ambiguity may be removed by the congruence $\frac{1}{2}x\equiv 1$, mod Δ. But when the exponent of p is >2, x is never completely determined by the congruence for the modulus p.

It is very remarkable that the exponent of p in the formula (A) is precisely the number of improperly primitive classes of determinant $-\Delta$, and in the formula (B) is precisely the number of properly primitive classes of determinant $-\Delta$*.

Before Dirichlet's discovery of the formulæ expressing the number of classes of quadratic forms of a given determinant, Jacobi, having succeeded in determining the exponent of p in the formula (A), for the case in which Δ is a prime number, was led with singular sagacity to conjecture that $\frac{\Sigma b-\Sigma a}{\Delta}$ must represent the number of improperly primitive classes of deter-

* See Art. 104 of this Report. When Δ is of the form $4n+3$, the two expressions given by Dirichlet for the number of properly primitive classes of determinant $-\Delta$ are $\left(2-\left(\frac{2}{\Delta}\right)\right)\frac{(\Sigma b-\Sigma a)}{\Delta}$, and $A-B$, where A and B represent the numbers of residues inferior to $\frac{1}{2}\Delta$, and satisfying the conditions $\left(\frac{a}{\Delta}\right)=+1$ and $\left(\frac{b}{\Delta}\right)=-1$ respectively. Hence $\frac{\Sigma b-\Sigma a}{\Delta}$ is the number of improperly primitive classes; because that number is equal to or is one-third of the number of properly primitive classes, according as $\Delta\equiv 7$, or $\equiv 3$, mod 8 (see Art. 103 or 113).

There is no difficulty in showing that Dirichlet's two expressions are identical. If $\left(\frac{2}{\Delta}\right)=1$, the congruence $2b'\equiv b$, mod Δ, is always resoluble; and if b receive in succession all positive values less than Δ which satisfy the condition $\left(\frac{b}{\Delta}\right)=-1$, b' will obtain the same values in a different order. Hence $\Sigma\frac{b}{\Delta}=2\frac{\Sigma b'}{\Delta}-\Sigma\frac{b}{\Delta}=\Sigma\frac{2b'-b}{\Delta}$. But if $b'<\frac{1}{2}\Delta$, $2b'-b=0$; if $b'>\frac{1}{2}\Delta$, $2b'-b=\Delta$, *i. e.* $\Sigma\frac{b}{\Delta}=A$, for there are A values of b greater than $\frac{1}{2}\Delta$. Similarly $\Sigma\frac{a}{\Delta}=B$, so that $\frac{\Sigma b-\Sigma a}{\Delta}=A-B$. In precisely the same manner it may be shown, if $\left(\frac{2}{\Delta}\right)=-1$, by considering the congruences $2b'+b\equiv 0$, mod Δ, $2a'+a\equiv 0$, mod Δ, that $3\frac{\Sigma b}{\Delta}=\Sigma\frac{2b'+b}{\Delta}=2A+B$ and $\frac{3\Sigma a}{\Delta}=\Sigma\frac{2a'+a}{\Delta}=2B+A$; whence

$$3\frac{\Sigma b-\Sigma a}{\Delta}=A-B.$$

Also the expression given in Art. 104 coincides with $A-B$. For that expression may be written in the form

$$-\left(\frac{2}{\Delta}\right)\Sigma\left(\frac{\Delta-2a'}{\Delta}\right)-\frac{2}{\Delta}\Sigma\left(\frac{\Delta-2b'}{\Delta}\right)=\Sigma\left(\frac{a'}{\Delta}\right)-\Sigma\left(\frac{b'}{\Delta}\right)=A-B,$$

a' and b' representing numbers less than $\frac{1}{2}\Delta$.

If we consider, as Cauchy has done, the product $\frac{\Pi[F(\theta^{-an})]^2}{\Pi F(\theta^{-2an})}$, the exponent of p in the formula (A) will be $A-B$. That product is evidently equal to $\Pi F(\theta^{-an})$, or to $\frac{\Pi[F(\theta^{-an})]^2}{\Pi F(\theta^{-bn})}$,

minant $-\Delta$*. If h is the number of classes in the principal genus of improperly primitive forms of determinant $-\Delta$, it follows from the theory of composition of quadratic forms that $2p^h$ can always be represented primitively by the principal form in that genus, *i. e.* by the form $\left(2, 1, +\frac{\Delta+1}{2}\right)$, and that the exponent of the lowest power of p which is capable of such representation is either h or a submultiple of h. Again, the equation

$4p^{\frac{\Sigma b-\Sigma a}{\Delta}}=x^2+\Delta y^2$, if we write in it $2X+Y$ for x, and Y for y, becomes $2p^{\frac{\Sigma b-\Sigma a}{\Delta}}=\left(2, 1, \frac{\Delta+1}{2}\right)(X, Y)^2$, the values of X and Y being integral. Assuming, then, that there exist primes of the linear form $n\Delta+1$, the doubles of which are capable of representation by a class appertaining to the exponent h (an assumption which implies that $-\Delta$ is not an irregular determinant, at least in respect of its improperly primitive classes), we see that in the case in which Δ is a prime of the form $4n+3$, and in which therefore there is but one genus of improperly primitive forms, $\frac{\Sigma b-\Sigma a}{\Delta}$ must be equal either to the number of improperly primitive classes, or to a multiple of that number; and as Jacobi found, upon a sufficient induction, that h was always equal to $\frac{\Sigma b-\Sigma a}{\Delta}$, he did not scruple to enunciate the theorem as true. We know, however, from an account which Dirichlet has given of a communication made to him by Jacobi, that Jacobi never obtained a demonstration of the theorem; and, indeed, it would seem probable, as has been observed by Dirichlet, that its demonstration requires other principles (Crelle, vol. lii. p. 206).

It is hardly necessary to add that when there is more than one genus of forms of determinant $-\Delta$, *i. e.* in every case except when Δ is a prime of the form $4n+3$, the exponent of p in the formulæ (A) and (B) is always a multiple of the least exponent for which those formulæ can be satisfied.

122. *Extension of the preceding Theory by Eisenstein.*—In the theory of which an account has been given in the last article, the prime number p is throughout supposed of the linear form $n\Delta+1$ or $4n\Delta+1$; thus in the equations $p=x^2+7y^2$, $p=x^2+8y^2$, we have supposed p to be of the forms $7n+1$ and $8n+1$ respectively. But we know that some power of every prime of which $-\Delta$ is a quadratic residue is capable of representation by the form $x^2+\Delta y^2$; and, in particular, that primes of the form $8n+3$ are capable of representation by x^2+2y^2, and primes of either of the forms $7n+2$ or $7n+4$

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according as $\left(\frac{2}{\Delta}\right)=+1$ or $=-1$; a result which is in accordance with the equation

$$A-B=\left(2-\left(\frac{2}{\Delta}\right)\right)\frac{(\Sigma b-\Sigma a)}{\Delta}.$$

In the formula (B), the exponent of p, obtained by the consideration of the same product, is $A'-B'=2\times\frac{(\Sigma b-\Sigma a)}{4\Delta}$; A' and B' denoting respectively the numbers of residues of the classes a and b respectively, which are inferior to 2Δ.

* Crelle, vol. ix. p. 189. Jacobi counts the classes of the prime determinant $-\Delta$ on the principle of Legendre, not distinguishing opposite classes from one another. If n is the number of improperly primitive classes so counted, we have $h=2n-1$, because there is but one improperly primitive ambiguous class. When Δ is of the form $8n+7$, Jacobi enunciates the theorem with reference to the number of properly primitive classes, which in this case is equal to the number of improperly primitive classes.

by x^2+7y^2. M. Stern found by induction that the value of x in the equation

$$p=8n+3=x^2+2y^2$$

satisfies the congruences

$$x\equiv-\frac{1}{2}\frac{\Pi 4n+1}{\Pi n\,.\,\Pi 3n+1},\ \text{mod}\,p,\ x\equiv(-1)^n,\ \text{mod}\ 4\ *;$$

and Eisenstein succeeded in demonstrating this theorem, as well as the two following†:—

"If $p=7n+2=x^2+7y^2$,

$$x\equiv\frac{1}{2}\frac{\Pi 3n}{\Pi n\,.\,\Pi 2n},\ \text{mod}\,p;\ x\equiv 3,\ \text{mod}\ 7;\text{"}$$

"If $p=7n+4=x^2+7y^2$,

$$x\equiv\frac{1}{2}\frac{\Pi 3n+1}{\Pi n\,.\,\Pi 2n+1},\ \text{mod}\,p;\ x\equiv 2,\ \text{mod}\ 7.\text{"}$$

These demonstrations are obtained by expressing the prime number p as the product of two complex factors, composed of 8th or 7th roots of unity. But the decomposition of p is no longer supplied by the formula of Art. 30; nor are the complex factors included in the definition of the functions ψ, which have been considered in Art. 30 and in the last Article.

If $p=8n+3$ is a real prime, p is also a prime in the theory of complex numbers of the form $a+bi$; let γ be a primitive root of p in that theory, and let $\gamma^y\equiv 1+iz$, mod p, z representing one of the real integers, $0, 1, \ldots p-1$. Also let $\psi(\omega)=\Sigma\omega^y$, ω denoting a primitive 8th root of unity, and the summation extending to every value of y. Eisenstein establishes the equations $\psi(\omega)\psi(\omega^{-1})=p$, $\psi(\omega)=\psi(\omega^3)$; whence $\psi(\omega)$ is of the form $A+B(1+i)\omega$, and $p=\psi(\omega)\psi(\omega^{-1})=A^2+2B^2$. To find the residue of A, mod p, let

$$e=\tfrac{1}{8}(p^2-1)=3n+1+np;$$

and write successively γ^e and γ^{5e} for ω in the function $\psi(\omega)$. We find

$$\psi(\gamma^e)=\Sigma\gamma^{ey}\equiv\Sigma(1+iz)^e\equiv\Sigma(1+iz)^{3n+1}(1-iz)^n,\ \text{mod}\,p,$$

because in general $(a+bi)^p\equiv(a-bi)$, mod p. In this expression no power of z has an exponent divisible by $p-1$; but $\Sigma_{z=0}^{z=p-1}z^\theta\equiv 0$, mod p, unless θ is different from zero, and is a multiple of $p-1$; therefore $\psi(\gamma^e)\equiv 0$, mod p. Again, because $5e=7n+2+(5n+1)p$, $\psi(\gamma^{5e})\equiv\Sigma(1+zi)^{7n+2}\ (1-zi)^{5n+1}$, mod p; in this expression the coefficient C of z^{p-1} is

$$\Sigma_\mu(-1)^{1+\mu'}\frac{\Pi 7n+2\ \Pi 5n+1}{\Pi\mu\ \Pi 7n+2-\mu\ \Pi\mu'\ \Pi 5n+1-\mu'},$$

where $\mu+\mu'=p-1$, and the summation extends from $\mu=3n+1$ to $\mu=7n+2$. Writing $3n+1+\nu$ for μ, $5n+1-\nu$ for μ', and observing that

$$\Pi\mu\,.\,\Pi\mu'\equiv(-1)^{1+\mu'},\ \text{mod}\ p,$$

we find

$$C\equiv\Sigma_{\nu=0}^{\nu=4n+1}\frac{\Pi 7n+2\,.\,\Pi 5n+1}{\Pi 4n+1-\nu\,.\,\Pi\nu}\equiv\frac{\Pi 7n+2\,.\,\Pi 5n+1}{\Pi 4n+1}\times\Sigma_{\nu=0}^{\nu=4n+1}\frac{\Pi 4n+1}{\Pi\nu\,.\,\Pi 4n+1-\nu}$$

$$\equiv\frac{\Pi 7n+2\,.\,\Pi 5n+1}{\Pi 4n+1}\times 2^{4n+1}\equiv\frac{\Pi 4n+1}{\Pi n\,.\,\Pi 3n+1},\ \text{mod}\,p,$$

* Crelle, vol. xxxii. p. 89. We enunciate the latter part of the theorem in the form in which it has been given by Eisenstein.

† Crelle, vol. xxxvii. p. 97.

observing that $2^{4n+1} \equiv -1$, mod p, and transforming each of the three factorials by Sir J. Wilson's theorem. Hence, finally,

$$A \equiv \frac{1}{2}\psi(\gamma^e) + \frac{1}{2}\psi(\gamma^{5e}) \equiv -\frac{1}{2}C \equiv -\frac{1}{2}\frac{\Pi 4n+1}{\Pi n.\Pi 3n}, \text{ mod } p,$$

in accordance with the enunciation of M. Stern. The congruence $A \equiv (-1)^n$, mod 4, is inferred by Eisenstein from the values of $\psi(1)$, $\psi(-1)$, $\psi(i)$, $\psi(-i)$; but we may omit these determinations here.

If $p=7n+2$, or $7n+4$, Eisenstein considers the complex numbers formed with the roots of the equation $\eta^3-21\eta-7=0$. If ω is an imaginary seventh root of unity, and $\eta_k=3(\omega^k+\omega^{-k})+1$, the roots of this equation are η_1, η_2, η_3; and every complex number formed with them is of the type $a+b\eta_1+c\eta_2$, a, b, c denoting real integral numbers. Let γ be a primitive root of p in this complex theory (p is a prime of the theory, because the congruence $\eta^2-21\eta-7\equiv 0$, mod p, is irresoluble: see Art. 44 of this Report), and let $\gamma^y \equiv 1+z_1\eta_1+z_2\eta_2$, mod p, z_1 and z_2 each representing any term of the series $0, 1, 2, \ldots p-1$. The function $\psi(\omega)=\Sigma\omega^y$ (the summation extending to all the p^2 values of y) is shown by Eisenstein to satisfy the equations

$$\psi(\omega)=\psi(\omega^2)=\psi(\omega^4), \quad \psi(\omega^3)=\psi(\omega^5)=\psi(\omega^6), \quad \psi(\omega)\times\psi(\omega^{-1})=p;$$

whence $\psi(\omega)$ is of the form $a+b(\omega+\omega^2+\omega^4)+c(\omega^3+\omega^5+\omega^6)$, and $p=A^2+7B^2$; if $A=a-\frac{1}{2}(b+c)$, $B=\frac{1}{2}(b-c)$. The equation $p^2=a+3b+3c$, considered as a congruence, mod 7, becomes $A\equiv p^2$, mod 7; *i. e.* $A\equiv 4$, or $\equiv 2$, mod 7, according as p is of the form $7n+2$ or $7n+4$. To obtain the congruence, mod p, which is satisfied by A, we consider the congruence $2A\equiv\psi(\gamma^e)+\psi(\gamma^{3e})$, mod p; in which $e=\frac{1}{7}(p^3-1)=\alpha+\beta p+\gamma p^2$, α, β, γ representing positive integers less than p, of which the sum will be found to be $p-1$. Now $\psi(\gamma^e)=\Sigma\gamma^{ey}\equiv\Sigma_0^{p-1}\Sigma_0^{p-1}(1+z_1\eta_1+z_2\eta_2)^\alpha\times(1+z_1\eta_p+z_2\eta_{2p})^\beta$ $\times(1+z_1\eta_{p^2}+z_2\eta_{2p^2})^\gamma$, mod p_0; because in general $[f(\eta_1)]^p\equiv f(\eta_p)$, mod p. Hence $\psi(\gamma^e)\equiv 0$, mod p, because $\alpha+\beta+\gamma=p-1$, and because $\Sigma_0^{p-1}\Sigma_0^{p-1}z_1^{\theta_1}z_2^{\theta_2}\equiv 0$, mod p, unless θ_1 and θ_2 are both different from zero, and both divisible by $p-1$. Again, if $3e=\alpha'+\beta'p+\gamma'p^2$, we find $\alpha'+\beta'+\gamma'=2(p-1)$; and omitting terms in which the sum of the indices of z_1 and z_2 is inferior to $2(p-1)$,

$$\psi(\gamma^{3e})\equiv\Sigma_0^{p-1}\Sigma_0^{p-1}(z_1\eta_1+z_2\eta_2)^{\alpha'}(z_1\eta_p+z_2\eta_{2p})^{\beta'}(z_1\eta_{p^2}+z_2\eta_{2p^2})^{\gamma'}, \text{ mod } p.$$

Substituting for $z_1\eta_{p^2}+z_2\eta_{2p^2}$ its value $-z_1\eta_1-z_2\eta_2-z_1\eta_p-z_2\eta_{2p}$, we obtain

$$\psi(\gamma^{3e})\equiv\Pi\alpha'.\Pi\beta'.\Pi\gamma'\,\Sigma_0^{p-1}\Sigma_0^{p-1}(z_1\eta_1+z_2\eta_2)^{p-1}(z_1\eta_p+z_2\eta_{2p})^{p-1}, \text{ mod } p;$$

because every such sum as $\Sigma_0^{p-1}\Sigma_0^{p-1}(z_1\eta_1+z_2\eta_2)^{p-1+\theta}(z_1\eta_p+z_2\eta_{2p})^{p-1-\theta}$, in which θ is one of the numbers $1, 2, 3, \ldots p-1$, taken positively or negatively, is certainly $\equiv 0$, mod p, as may be seen by substituting $(z_1\eta_p+z_2\eta_{2p})$ for $(z_1\eta_1+z_2\eta_2)^p$. Lastly, the coefficient C of $(z_1z_2)^{p-1}$ in the expression $\Sigma_0^{p-1}\Sigma_0^{p-1}$ $(z_1\eta_1+z_2\eta_2)^{p-1}(z_1\eta_p+z_2\eta_{2p})^{p-1}$ is evidently $\Sigma_{\mu=0}^{\mu=p-1}K^2_\mu(\eta_1\eta_{2p})^\mu(\eta_2\eta_p)^{p-1-\mu}$, K_μ representing the coefficient of x^μ in the expansion of $(1+x)^{p-1}$. Hence $C\equiv(\eta_1\eta_{2p}-\eta_2\eta_p)^{p-1}\equiv 1$, mod p, because $\eta_1\eta_{2p}-\eta_2\eta_p=\pm 21$; so that finally

$$A\equiv\tfrac{1}{2}\Pi\alpha'.\Pi\beta'.\Pi\gamma'\,\Sigma_0^{p-1}\Sigma_0^{p-1}(z_1z_2)^{p-1}\equiv\tfrac{1}{2}\Pi\alpha'.\Pi\beta'.\Pi\gamma', \text{ mod } p;$$

an expression which, on substituting for α', β', γ' their values in the two

cases $p=7n+2$, $p=7n+4$, will be found to coincide with the formulæ given by Eisenstein.

There can be no doubt that the principles of this method are capable of many other applications; but nothing has as yet been added to these researches of Eisenstein.

123. *Applications of Continued Fractions to the Theory of Quadratic Forms.*—Representations of a number by quadratic forms are in certain cases deducible from the development of its square root in a continued fraction. If A is any number not a square, $\frac{J_n+\sqrt{A}}{D_n}$ the $(n+1)$th complete quotient in the development of $\sqrt{A}$, $\frac{p_n}{q_n}$ the convergent fraction immediately preceding that complete quotient, so that $p^2_n-Aq^2_n=(-1)^nD_n$, the form $(q^2_n, -p_n, A)$, of which the determinant is $(-1)^nD_n$, is either properly or improperly primitive, and belongs in either case to the principal genus of its order. If we investigate the transformation by which this form is reduced to the simplest form in its class, we shall obtain, by an operation exempt from all tentative processes, a representation of A by that simplest form. The following proposition, however, supplies a method by which, when q_n is uneven, and $(q^2_n, -p_n, A)$ belongs to the principal class of properly primitive forms, or when q_n is even, and $(\frac{1}{2}q^2_n, -p_n, 2A)$ belongs to the principal class of improperly primitive forms, we can frequently infer from the development of $\sqrt{A}$ itself the solution of the equations

$$X^2-(-1)^nD_nY^2=A, \quad 2X^2+2XY+\frac{1+(-1)^{n+1}D_nY^2}{2}=A.$$

"If (a, b, c), (a', b', c') are two primitive forms of the determinants D and D′, whose joint invariant $ac'-2bb'+ca'$ is zero, and if m and m' are the greatest common divisors of a, $2b$, c; a', $2b'$, c'; m^2D' and m'^2D are respectively capable of primitive representation by the duplicates of (a, b, c) and $a', b', c')$."

Thus if (a', b', c') is properly primitive and ambiguous, D can be represented primitively by $(1, 0, -D')$; if (a', b', c') is improperly primitive and ambiguous, 2D can be represented by $\left(2, 1, \frac{1-D'}{2}\right)$. For (a,b,c) and (a',b',c') let us take $(1, 0, -A)$ and $(q_n, -p_n, q_nA)$, whose joint invariant is zero, and of which the first is properly primitive; while the second is properly or improperly primitive according as q_n is uneven or even, and has for its duplicate in the former case $(q^2_n, -p_n, A)$, in the latter $2\times(\frac{1}{2}q^2_n, -p_n, 2A)$: so that it is ambiguous in both cases alike. Further, let us represent by $(\epsilon_s, -\delta_s, \epsilon_{s-1})$ the form into which $(q_n, -p_n, q_nA)$ is transformed by $\begin{vmatrix} p_s, p_{s-1} \\ q_s, q_{s-1} \end{vmatrix}$; we infer, from the property of the invariants, the equations

$$(-1)^{n+1}D=\epsilon_s\,\epsilon_{s-1}-\delta^2_s, \quad \epsilon_{s-1}\,D_s-2\delta_s\,J_s-\epsilon_s\,D_{s-1}=0.$$

Let us first suppose that n is uneven, so that $(-1)^nD_n$ is a negative determinant which we shall call $-\Delta$; since

$$q_n(q_nx^2-2p_nxy+q_nAy^2)=(q_nx-p_ny)^2+\Delta y^2,$$

it is evident that when $q_nx^2-2p_nxy+q_nAy^2$ attains its minimum value, $\frac{x}{y}$ is a convergent to $\frac{p_n}{q_n}$; not, we may add, the last convergent, if the last integral quotient in the development of $\frac{p_n}{q_n}$ is unity. If therefore $(q_n, -p_n,$

$q_n A)$ is properly primitive and of the principal class, we shall have, for some value of s, $\epsilon_s=1$; whence

$$D_{s-1}=-2\delta_s J_s+\epsilon_{s-1}D_s, \text{ and } A=J^2_s+D_s D_{s-1}=(J_s-\delta_s D_s)^2+\Delta D^2_s.$$

If $(q_n, -p_n, q_n A)$ is improperly primitive, and of the principal class of its order, we shall have for some value of s, $\epsilon_s=2$, $D_{s-1}=-\delta_s J_s+\frac{1}{2}\epsilon_{s-1}D_s$,

$$2A=2\left(J_s-\frac{\delta_s+1}{2}D_s\right)^2+2\left(J_s-\frac{\delta_s+1}{2}D_s\right)D_s+\frac{\Delta+1}{2}D^2_s.$$

We may therefore enunciate the theorem: "If $\frac{p_n}{q_n}$ is an inferior convergent to $\sqrt{A}$, and $\Delta=q^2_n A-p^2_n$; when $(q_n, -p_n, q_n A)$ is of the principal class of forms of determinant $-\Delta$, A is of the form $X^2+\Delta Y^2$, and Y is the denominator of a complete quotient in the development of $\sqrt{A}$; when $(q_n, -p_n, q_n A)$ is of the principal class of improperly primitive forms of determinant $-\Delta$, A is of the form $2X^2+2XY+\frac{\Delta+1}{2}Y^2$, and Y is the denominator of a complete quotient in the development of $\sqrt{A}$."

When $(q_n, -p_n, q_n A)$ is ambiguous and properly primitive, but of some other class than the principal class, we must distinguish between two cases, that in which the reduced form equivalent to $(q_n, -p_n, q_n A)$ is itself an ambiguous form, and that in which it is of the type (a, b, a). In the former case we shall arrive at a form $(\epsilon_s, -\delta_s, \epsilon_{s-1})$, in which ϵ_s, being the least number which can be represented by $(q_n, -p_n, q_n A)$, is a divisor of $2\delta_s$, and consequently of D_s and 2Δ; and we shall find

$$A=\left(J_s-\delta_s\frac{D_s}{\epsilon_s}\right)^2+\Delta\frac{D^2_s}{\epsilon^2_s}.$$

In the latter case we shall, in the series of forms $(\epsilon_s, -\delta_s, \epsilon_{s-1})$, arrive at a sequence of one or other of the three types: (1), $(2[a-b], -[a-b], a)$, $(a, a-b, 2[a-b])$; (2), $(a, -[a-b], 2[a-b])$, (a, b, a); (3), $(a, -b, a)$, $(2[a-b], a-b, a)$; *i. e.* we shall arrive at a form in which ϵ_s is the least number but one, which can be represented by $(q_n, -p_n, q_n A)$, and is a divisor of D_s and 2Δ; we shall then find

(1) $$A=(J_s-\tfrac{1}{2}D_s)^2+\Delta\frac{D^2_s}{\epsilon^2_s};$$

(2) $$A=(J_{s+1}+\tfrac{1}{2}D_s)^2+\Delta\frac{D^2_s}{\epsilon^2_s};$$

(3) $$A=(J_s+\tfrac{1}{2}D_s)^2+\Delta\frac{D^2_s}{\epsilon^2_s}.$$

Similar results may be enunciated for the case in which $(q_n, -p_n, q_n A)$ is improperly primitive and ambiguous, but not of the principal class.

In applying the preceding formulæ to particular cases, the following theorem of Goepel's is very useful. Since

$$\epsilon_s=q_n p^2_s-2p_n p_s q_s+Aq_n q^2_s,\ -\delta_s=q_n p_s p_{s-1}-p_n(p_s q_{s-1}+p_{s-1}q_s)+Aq_n q_s q_{s-1},$$

we find, if μ_s is the integral quotient immediately succeeding $\frac{p_s}{q_s}$, that $\delta_{s+1}=\delta_s-\mu_s\epsilon_s$. Hence $\delta_1, \delta_2 \ldots$ form a continually decreasing series. But $\delta_1=p_n$ is positive, and $\delta_n=-\Delta q_{n-1}$ is negative; there exists, therefore, a pair of consecutive terms δ_s and δ_{s+1}, of which the former is positive, or zero,

and the second negative; Goepel shows that $-\delta_s\,\delta_{s+1}<\Delta$. For we find $q_s\epsilon_{s-1}+q_{s-1}\delta_s=(-1)^s(q_np_{s-1}-p_nq_{s-1})$, $q_s\delta_s+q_{s-1}\epsilon_s=(-1)^{s+1}(q_np_s-p_nq_s)$; *i. e.*

$$\frac{q_s\,\epsilon_{s-1}+q_{s-1}\,\delta_s}{q_s\,\delta_s+q_{s-1}\,\epsilon_s}=\mu_s+\frac{1}{\mu_{s+1}}+\ldots;$$

whence

$$q_s\,\epsilon_{s-1}+q_{s-1}\,\delta_s>\mu_s(q_s\,\delta_s+q_{s-1}\,\epsilon_s);$$

or multiplying by ϵ_s,

$$\Delta q_s>-\delta_s\,\delta_{s+1}\,q_s-\epsilon_s\,\delta_{s+1}\,q_{s-1};$$

that is, $\Delta>-\delta_s\,\delta_{s+1}$, because δ_{s+1} is negative.

Thus if $\Delta=1$, we have necessarily $\delta_s=0$; whence $\epsilon_s=\epsilon_{s-1}=1$, $D_{s-1}=D_s$, $A=J^2_s+D^2_s$. If $\Delta=2$, we have either

(1) $\quad\delta_s=0,\quad \epsilon_{s-1}=2,\quad \epsilon_s=1,\quad D_{s-1}=2D_s,\quad A=J^2_s+2D^2_s$;

or (2) $\quad\delta_s=0,\quad \epsilon_{s-1}=1,\quad \epsilon_s=2,\quad D_s=2D_{s-1},\quad A=J^2_s+2D^2_{s-1}$;

or (3) $\quad\delta_s=1,\quad \delta_{s+1}=-1,\quad \mu_s=2,\quad \epsilon_s=1,\quad \epsilon_{s-1}=\epsilon_{s+1}=3$;

$$D_{s-1}=3D_s-2J_s,\quad A=(J_s-D_s)^2+2D^2_s=(J_{s+1}-D_s)^2+2D^2_s.$$

If $\Delta=3$, we have either

(1) $\quad\delta_s=0,\quad \epsilon_{s-1}=3,\quad \epsilon_s=1,\quad D_{s-1}=3D_s,\quad A=J^2_s+3D^2_s$;

or (2) $\quad\delta_s=0,\quad \epsilon_{s-1}=1,\quad \epsilon_s=3,\quad D_s=3D_{s-1},\quad A=J^2_s+3D^2_{s-1}$;

or (3) $\quad\delta_s=1,\quad \delta_{s+1}=-2,\quad \mu_s=3,\quad \epsilon_s=1,\ \epsilon_{s-1}=4,\ D_{s-1}=4D_s-2J_s$

$$A=(J_s-D_s)^2+3D^2_s;$$

or (4) $\quad\delta_s=2,\quad \delta_{s+1}=-1,\ \mu_s=3,\ \epsilon_s=1,\ \epsilon_{s+1}=4,\ D_{s+1}=4D_s-2J_{s+1}$,

$$A=(J_{s+1}-D_s)^2+3D^2_s;$$

or (5) $\quad\delta_s=1,\quad \delta_{s+1}=-1,\quad \mu_s=2,\quad \epsilon_s=1,\quad \epsilon_{s-1}=\epsilon_{s+1}=4$,

$$D_{s-1}=4D_s-2J_s,\quad A=(J_s-D_s)^2+3D^2_s;$$

or (6) $\quad\delta_s=1,\ \delta_{s+1}=-1,\ \mu_s=1,\ \epsilon_s=\epsilon_{s-1}=\epsilon_{s+1}=2$; $D_{s-1}=D_s-J_s=J_{s+1}$

$$D_{s+1}=D_s-J_{s+1}=J_s,\quad A=J^2_s-D_s\,J_s+D^2_s=J^2_{s+1}-D_s\,J_{s+1}+D^2_s;$$

the last case occurring always and only when q_n is even. If $\Delta=7$, and if we suppose q_n even, so that $(q_n, -p_n, q_nA)$ is improperly primitive, we shall certainly arrive at a form $(\epsilon_s, -\delta_s, \epsilon_{s-1})$, in which $\delta_s=\pm1$, and either $\epsilon_s=2$, $\epsilon_{s-1}=4$, or *vice versâ* $\epsilon_{s-1}=2$, $\epsilon_s=4$; so that there are four cases

$$(1,\,2)\ \pm J_s=2D_{s-1}-D_s,\quad A=J^2_s\mp J_sD_{s-1}+2D^2_{s-1},$$

$$(3,\,4)\ \pm J_s=2D_s-D_{s-1},\quad A=J^2_s\mp J_sD_s+2D^2_{s-1}.$$

Let us next suppose that n is even, so that $(-1)^nD_n=\Delta$ is a positive determinant. Then it is evident $\delta_1\ \delta_2\ldots$ are all positive, for

$$q_n\delta_s=-(q_np_s-p_nq_s)(q_np_{s-1}-p_nq_{s-1})+\Delta q_sq_{s-1},$$

of which both parts are positive. Again, the numbers $\epsilon_1, \epsilon_2\ldots$ form a continually decreasing series; for $q_n\epsilon_s=(q_np_s-p_nq_s)^2-\Delta q^2_s$; of which the positive part continually decreases, and the negative increases in absolute magnitude. But $\epsilon_1=q_n$, and $\epsilon_n=-\Delta q_n$; there exists, therefore, a term ϵ_{s-1} which is positive, while the following term ϵ_s is negative; whence $\delta^2_s=\Delta+\epsilon_s\epsilon_{s-1}<\Delta$.

Thus if $\Delta=2$, we shall have $\delta_s=1$, $\epsilon_{s-1}=1$, $\epsilon_s=-1$, $2J_s=D_s+D_{s-1}$, $A=(J_s+D_s)^2-2D^2_s=(J_s+D_{s-1})^2-2D^2_{s-1}$. If $\Delta=3$, we shall have either (1) $\delta_s=1$, $\epsilon_{s-1}=1$, $\epsilon_s=-2$, $2J_s=D_s+2D_{s-1}$, $A=(J_s+D_{s-1})^2-3D^2_{s-1}$; or (2) $\delta_s=1$, $\epsilon_{s-1}=2$, $\epsilon_s=-1$, $2J_s=2D_s+D_{s-1}$, $A=(J_s+D_s)^2-3D^2_s$.

If a is the integral number immediately inferior to $\sqrt{A}$, the period of integral quotients in the development of $\sqrt{A}$ is of the type

$$\mu_1, \mu_2, \dots \mu_{k-1}, b, \mu_{k-1}, \mu_{k-2}, \dots \mu_1, 2a;$$

and it is sometimes possible to assign *à priori* the value of D_k, the denominator of the complete quotient corresponding to b; for that denominator is always a divisor of $2A$, and is besides $<2\sqrt{A}$. Thus if A is a prime, $D_k=1$ or 2; if $\frac{1}{2}A$ is a prime, $D_k=1$, 2, or 4. Hence if A or $\frac{1}{2}A$ is a prime of the form $4n+1$, $(-1)^kD_k=-1$; for the equations $x^2-Ay^2=\pm 2$, $=\pm 4$ are impossible on the supposition that x and y are relatively prime, and the equation $x^2-Ay^2=1$ is inadmissible, because b is not the last quotient of a period. Similarly if A or $\frac{1}{2}A$ is a prime of the form $4m+3$, $(-1)^kD_k=2$ or -2, according as the prime is of the form $8m+7$ or $8m+3$; if $\frac{1}{3}A$ is a prime of the form $4m+3$, $(-1)^kD_k=+3$ or -3, according as the prime is of the form $12m+11$ or $12m+7$; and, in general, if λ and $\frac{A}{\lambda}$ are each of them primes of the form $4n+3$, and if $2\lambda<\sqrt{A}$, $(-1)^kD_k=\lambda$, or $-\lambda$, according as λ is or is not a quadratic residue of $\frac{A}{\lambda}$. We thus obtain a direct method for the representation of primes of the forms $4m+1$, $8m+3$, $8m+7$, or the doubles of such primes, by the forms x^2+y^2, x^2+2y^2, x^2-2y^2: when λ is a prime of the form $12m+7$, the developments of $\sqrt{\frac{\lambda}{3}}$ and $2\sqrt{\frac{\lambda}{3}}$ will give representations of 3λ by the forms x^2-xy+y^2, x^2+3y^2: when λ is a prime of one of the forms, $28m+11$, $28m+15$, $28m+23$, the development of $\sqrt{\frac{\lambda}{7}}$ will give a representation of 7λ by the form $x^2-xy+2y^2$, &c.

The theorem relating to primes of the form $4n+1$ is very celebrated; it was established independently by Gauss and Legendre, and it no doubt suggested the researches of Goepel in his doctoral dissertation 'De quibusdam æquationibus indeterminatis secundi Gradûs' (Crelle, vol. xlv. pp. 1–13). Goepel confined his investigation to the case $D_n=2$, though his method, which in the main is that here described, is of a much more general character. The theorems relating to the case $\Delta=-3$ were first given by M. Stern, who employs Goepel's method with very little modification (Crelle, vol. liii. pp. 87–98). A paper by M. Hermite, which appeared in Crelle's Journal (vol. xlv. p. 191) prior to the republication there of Goepel's dissertation, contains a method (see pp. 211–213) which is very similar to that of Goepel, but which does not connect itself so readily with the common theory of continued fractions. In these researches of M. Hermite the invariant $ac'-2bb'+a'c$ appears explicitly; which is not the case in Goepel's paper.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MATHEMATICS AND PHYSICS.

Mathematics.

Address of the President, Professor W. J. Macquorn Rankine, *F.R.S.*

The President, on taking the chair, said that the quantity of business before the Section was so great that the utmost economy of time would be necessary in order to dispatch that business in a satisfactory manner. For that reason the Committee had instructed him to recommend to the Section the observance of the following rules in conducting discussions:—That immediately after the reading of any paper, members should put such questions to the author as they might consider desirable for the purpose of making clear the meaning of the paper; that the author should answer those questions one by one; that after all the questions had been answered, such members as chose to make remarks on the subject of the paper should address the Section, each member being at liberty to speak once only on one paper; and that after all those remarks had been made, the author should reply to the whole discussion in one address. He trusted that the members of the Section would approve of the rules recommended by the Committee, and would support him in taking care that those rules should, as far as practicable, be observed.

On a certain Class of Mathematical Symbols.
By W. H. L. Russell, *A.B., F.R.S.*

In general, a mathematical symbol acting on a function of a variable gives rise to another function of that variable. Thus $\frac{d}{dx} f(x), \Delta f(x), \int dx f(x)$, and many other expressions, are all functions of (x). But there are certain symbols which, in their action on a function of a variable, produce expressions which, from their essential nature, are independent of that variable. Such is the symbol used by Cauchy in his 'Exercices' to denote the aggregate result obtained by multiplying a function of (x) successively by those simple factors which, equated to zero, make it infinite, and then substituting for x) the values obtained by equating those factors to zero. Such also is the symbol Θ used by Professor Boole in his researches on the comparison of transcendents, denoting the result obtained by subtracting from the

result derived by Cauchy's symbol just mentioned the coefficient of $\frac{1}{x}$ in the expansion of the given function in descending powers of (x). Now let $F\left(x, y, \frac{dy}{dx}, \frac{d^2y}{dx^2}, \frac{d^ny}{dx^n}\right)$ denote any function of x, y, and its differential coefficients. This is sometimes written $F(x, y, y_1, y_2, \ldots . y_n)$. Now there are investigations in which we require the value of $\frac{d^mF}{dy_n^m}$, where y_n is put equal to zero after the differentiation is performed. The writer has found a symbol such as Z_n^m to denote this, of great utility in the treatment of differential equations; and it will be observed that it belongs to the second class of symbols here mentioned.

On the Quantity and Centre of Gravity of Figures given in Perspective, or Homography. By Professor SYLVESTER, *F.R.S.*

In the first instance, the author showed how to find the point in the perspective representation of a plane figure into which the centre of gravity of such figure is projected. For this purpose it is only necessary to be furnished with the direction of the vanishing-line corresponding to the plane of the object put into perspective. The rule for finding the point in question is the following: every element of the picture is to be charged with a density equal to the inverse fourth power of its distance from the vanishing-line; the centre of gravity of the figure so charged will be the point required, and may of course be found by the rules of the integral calculus.

Next, as to the area of the unknown object. To determine this another datum (but only one other) is required besides the direction of the vanishing-line, which may be termed the constant of perspective, being determined when the position of the eye and that of the object-plane in reference to the picture are given. This constant is the product of the eye's distance from the vanishing-line into the square of the distance of the intersections of the object- and picture-planes from the same line. If now every element of the picture be charged with a density equal to the constant of perspective divided by the *cube* of the element's distance from the vanishing-line, the mass of the figures so charged will be the area of the unknown object-figure.

The author then proceeded to show how the area and the perspective centre, by aid of the preceding principles, admit of being reduced to depend on one single integral, closely analogous to the *potential* used in the theory of attractions to which he gives the name of *polar potential.* The polar potential of a plane figure in respect to a given line is defined to be the sum of the quotients of the elements by their respective distances from the line, and consequently the polar potential of the picture in respect to a vanishing-line in its plane becomes a function of the two parameters by which its position may be determined. The parameters which the author finds most convenient to employ are the distance of the vanishing-line from an arbitrary fixed point in the picture and the angle which it makes with a fixed line therein.

The author then supplied the formulæ (which are of a very simple character) for calculating the area of the object and the coordinates of its perspective centre of gravity, by means of differentiation processes performed upon the polar potential of the picture treated as a function of these parameters. He afterwards proceeded to extend the same method to figures, plane or solid, connected by the more general relation known under the name of homography, of which the relation between figures generated through the medium of perspective is only a particular kind. In the case of a solid figure, its polar potential in respect to a variable plane becomes a function of three parameters; and by means of differentiations performed upon it in respect to these parameters, the content and the coordinates of the point corresponding homographically to the centre of gravity of a solid figure may be expressed when its homograph and the position of a plane corresponding to the

points at infinity in the otherwise unknown figure are given in addition (as regards the content) to a certain constant termed the homographic determinant.

Professor Rankine threw out a suggestion as to the possibility of a practical application of the preceding theory to the stability of structures standing to each other in a certain simple relation of homography.

On the Conditions of the Resolvability of Homogeneous Algebraical Polynomials into Factors. By J. J. Walker.

In this communication a commencement was made of a systematic investigation of the conditions of resolvability of homogeneous polynomials of n variables into factors, and it was shown that in the case of the polynomial of the second degree the conditions are that every $n-3$rd "*minor*" of a symmetrical determinant, whose constituents are the coefficients of the polynomial, should vanish. It was also shown that the coefficients of the factors are roots of certain quadratic equations, and the general theory was illustrated by geometrical applications.

Astronomy.

On the Augmentation of the Apparent Diameter of a Body by its Atmospheric Refraction. By Stephen Alexander.

Professor Challis, in the Report of the Association for 1862, stated that there would be reason to expect, in a solar eclipse, that a slender band of the sun's disk immediately contiguous to the moon's border would be somewhat brighter than the other parts, and advised that especial attention should be directed to this point on the next occurrence of a solar eclipse.

The phenomenon thus ingeniously shown by Professor Challis to be in place *has* itself been *frequently observed.*

The author first noticed it in February 1831, at Berlin, Maryland, during the progress of the annular eclipse (Transactions of the Albany Institute, vol. ii. p. 85). It is mentioned in his notes as having been seen "during the first hour of the eclipse, with (at one time and another) different telescopes and screen glasses of different colours."

It has, almost without exception (perhaps with no exception), been seen by him in some seven or eight solar eclipses which he has since observed. Special attention was directed to its observation in this country in 1854; and its observation is recorded by Profs. Frazer and Kendall at Philadelphia in that year (Proc. of Amer. Phil. Soc. vol. vi. p. 41), also among his own observations of that eclipse at Ogdensburg, New York (Astronomical Journal, No. 75, p. 17). See also his Report of Observations in Labrador, July 1860, made to the Superintendent of the United States Survey (Report of the Superintendent for 1860, Appendix 21).

The daguerreotype impressions of the eclipse of 1854 (taken in New York) distinctly show the narrow bright band; and it can also be seen in the photographic impressions taken in July 1860, in Labrador. A careful inspection will, he presumes, reveal it in the instance of any good photographic impression of the partially eclipsed sun; especially where the dark limb of the moon is projected on a part of the sun's disk sufficiently near to the border of the same. The phenomenon is thus the most conspicuous when the eclipse is quite small or when it is very large.

On the Selenographical Relations between the Chain of Lunar Mountains the Alps with the Mare Imbrium and the Mare Frigoris. By W. R. Birt, *F.R.A.S. Communicated by* Dr. Lee, *F.R.S.*

The mountains on the lunar surface known as the Alps extend from the Caucasian range bordering the N.E. portion of the Mare Serenitatis to the dark-floored crater Plato, approaching nearly to the summit of its western rim. From the Caucasian

range to a point not very far west of Plato, the S.E. aspect of the Alps bordering the Mare Imbrium is precipitous—in this respect resembling most of the terrestrial chains of mountains bordering large oceans; and the mountains are much closer together and more chain-like than in the area towards the Mare Frigoris, where they are more or less detached the one from the other. A large extent of surface, presenting a great variety of character—mountainous, rugged, pierced with numerous craters, rising into an elevated crest, sometimes spreading out into considerable breadth, at others contracted to a narrow, neck-like kind of isthmus—extends from the Caucasus to the promontory La Place, which is the western jutting-point of the rugged and mountainous border of the Sinus Iridum. The western part of this rugged land is occupied by the Alps. The middle exhibits a decidedly raised character, in which Plato appears to have been "sunk." This walled plain is comparatively shallow. The eastern part of the tract above described is lower, and pierced with numerous craters, especially the portion immediately eastward of Plato; the largest crater (very much smaller indeed than Plato) being a conspicuous object under the morning and evening illuminations. The smooth surface of the Mare Imbrium comes closely up to the tract above described; and at some little distance from the border several isolated mountains, soft ridges, and small craters are scattered here and there on the surface of the Mare, which are conspicuous objects under every aspect of illumination. The immediate object of this paper was to solicit the attention of astronomers to a continuation of the Alps on the northern side of the Mare Frigoris. The Alps, as laid down on our lunar maps, do not extend beyond the bright ground N. and N.W. of Plato. The boundary common to this bright ground and the Mare Frigoris is exceedingly well defined: the contrast between the superior brilliancy of the one and the dark grey surface of the other is very marked. The bright ground, which is of the rugged character above mentioned, gradually rises from the Mare Frigoris to the summit of the ring of Plato; and the same is observable of the ascent on the south side from the surface of the Mare Imbrium, with the exception of the slight depression of the site of the ancient crater Newton (Schröter). In the Monthly Notices of the Royal Astronomical Society for May 1863, I described a remarkably dark border common to the Mare Imbrium, the Alps, and a bright portion extending from them to the south of Plato. Since writing that paper I have ascertained that this dark border is irrespective of any hypsometrical affections, in this respect resembling greatly the bright rays extending from the various ray-centres on the moon's surface, which alike cross every variety of depression and elevation. Under an early illumination, a soft and slightly elevated ridge, casting a well-defined shadow, is seen extending from a crater, Piazzi Smyth (which is some distance S.W. of Plato), to the small group of mountains of which λ, at the foot of the Hartwell Mountains, is the principal. The slight elevation of this ridge above the general surface of the Mare Imbrium and its continuity between Piazzi Smyth and Plato are well seen under both the morning and evening illuminations. The visibility of this ridge is fugitive; it disappears entirely under even a moderately high sun, and then the dark border, which is only manifested under an advanced stage of illumination, crosses it uninterruptedly. The dark border greatly resembles, although in an opposite sense, the broad light mark crossing Geminus under the mid-day illumination, which is described in my paper presented to the British Association in 1859. I have been somewhat particular in describing the independence of this dark border and any hypsometrical affections, as several patches of a similar kind are observed on the surface of the Mare Frigoris, especially near the centre. I have not yet detected much, if any, variation of level on the surface of the Mare Frigoris north of Plato, except a fault of an exceedingly well-marked character, not far from the opposite or northern border of the Mare Frigoris. This fault clearly indicates a well-marked difference of level between the southern part of the Mare Frigoris adjoining the bright ground north of Plato and the northern portion. It is in this immediate neighbourhood that the northern boundary of the Mare Frigoris is exceedingly rugged and rocky, running into several promontories which extend towards Plato; and these promontories, combined with the fault above alluded to, clearly indicate a superior level for the land extending between Timæus and Fontenelle north of the Mare Frigoris. Shortly after sunrise, and a little before sunset, this high land is seen to be

a continuation of the direction of the Alps. As before remarked, the Alpine chain is most perfect in the neighbourhood of the Mare Imbrium, viz. from a little north of Cassini to the west extremity of a bright portion of land extending from it to Plato—the chain being indented by the wedge-shaped valley; the portion of bright land has but few mountains on it, and a few craters have been opened upon it. North of this portion of bright land, several detached mountains are scattered over the surface, interspersed with but few craters; and this territory may be regarded as the continuation of the Alpine Mountains, as far as the southern boundary of the Mare Frigoris, by two well-marked groups of mountains west of Plato, the chain-like character and general direction being confined to the higher peaks bordering the Mare Imbrium. "Between this interesting group of rugged and mountainous land and the Alps, the Mare Frigoris intervenes at a lower level. The 'fault' before alluded to clearly indicates a sinking down of a portion of the surface of the Mare hereabouts, which is not only narrower than any other, but especially interesting from its being crossed by certain lucid streaks from the rayed crater Anaxagoras, which are more or less coincident with the promontories above mentioned." The strait-like character of this portion of the Mare Frigoris, the existence of considerable mountain masses on each side, the well-marked depression of the Mare below the group of mountains on the north, and the ascent on the south towards the rim of Plato strongly indicate the valley-like character of this part of the Mare Frigoris, and also that the group of mountains on the north may with great probability be regarded as a continuation of the great Alpine group on the south, a portion of the chain having been depressed when the valley of the Mare was produced.

On the relative Distances of the Planets from the Sun. By R. S. Browne.

The communication consisted of a new series of numbers which more closely approximate to the known distances of the planets from the sun than do those suggested by Bode, as shown in the following Table:—

Bode's Numbers.			Numbers proposed.		
1		4	1	4	4
2	4+3	7	2	4+ 3	7
3	4+2·3	10	3	7+ 4	11
4	$4+2^2 \cdot 3$	16	4	11+ 7	18
5	$4+2^3 \cdot 3$	28	5	18+ 11	29
6	$4+2^4 \cdot 3$	52	6	29+ 18+11	58
7	$4+2^5 \cdot 3$	100	7	58+ 29+18	105
8	$4+2^6 \cdot 3$	196	8	105+ 58+29	192
9	$4+2^7 \cdot 3$	388	9	192+105+58	355

On the Star Chromatoscope. By A. Claudet, *F.R.S.*

The scintillation and change of colours observed in looking at the stars are so rapid, that it is very difficult to judge of the separate lengths of their duration. If we could increase on the retina the length of the sensations they produce, we should have a better means of examining them. This can be done by taking advantage of the power by which the retina can retain the sensation of light during a fraction of time which has been found to be one-third of a second—a phenomenon which is exemplified by the curious experiment of a piece of incandescent charcoal revolving round a centre and forming a continual circle of light. It is obvious that if the incandescent charcoal during its revolution was evolving successively various rays, we could measure the length and duration of every ray by the angle each would subtend on the circle during its course. This is precisely what can be done with the light of the star. It can indeed be made to revolve like the incandescent charcoal, and form a complete circle on the retina. When we look at a star with a telescope, we see it on a definite part of the field of the glass; but if

with one hand we slightly move the telescope the image of the star changes its position; and during that motion, on account of the persistence of sensation on the retina, instead of appearing like a spot, it assumes the shape of a continuous line. Now if, instead of moving the telescope in a straight line, we endeavour to move it in a circular direction, the star appears like a circle, but very irregular, on account of the unsteadiness of the movement communicated by the hand. Such is the principle of the instrument employed by the author to communicate the perfect circular motion, which it is impossible to impart by the hand. The instrument consists of a conical tube placed horizontally on a stand, and revolving on its own axis by means of wheels; inside this tube a telescope or an opera-glass is placed, by which, by means of two opposite screws, the end of the object-glass can be placed in an excentric position in various degrees according to the effect desired, while the eye-glass remains in the centre of the small end of the tube. Now, we understand that when the machine makes the tube revolve upon its axis, the telescope inside revolves in an excentric direction, and during the revolution the star seen through it must appear like a circle. This circle exhibits on its periphery the various rays emitted by the star, all following each other in spaces corresponding with their duration, showing also blank spaces between two contiguous rays which must correspond with the black lines of the spectrum. The instrument, in fact, is a kind of spectroscope, by which we can analyse the light of any star, study the cause of the scintillation, and compare its intensity in various climates or seasons and at different altitudes.

On the Relationship between the Variation of the Excentricity of the Earth's Orbit and the Moon's Mean Motion in Longitude. By the Rev. Dr. E. Hincks.

One of the hieroglyphic inscriptions at Thebes contains a notice of an eclipse of the sun, observed on a given day of a given year of a certain king; but according to Hansen's tables, no eclipse could have been visible on that day so far west as Thebes. Dr. Hincks therefore asked for the assistance of those more practically engaged than himself in astronomical pursuits in answering the following queries:—Let e_0 and M_0 be the excentricity of the earth's orbit and the mean longitude of the moon at the beginning of 1801. Let e_T and M_T be the excentricity and the mean longitude at the end of any time T, the longitude being reckoned from the equinox of 1801.

$$\text{Let } e_T = e_0 + e_1 T + e_2 T^2$$
$$\text{and } M_T = M_0 + M_1 T + M_2 T^2 + M_3 T^3.$$

It was formerly thought that $M_2 = ae_1$ and $M_3 = a_1 e_2$; a and a_1 being coefficients supposed to be known. Some years ago it was discovered that these coefficients were much less than they had been supposed to be; and it was inferred that some other cause had combined with gravity to make M_2 so great as it is. Within the last year he had heard that some eminent astronomers were of opinion that e_1 was "much greater" than it had been supposed to be; but he had heard nothing precise as to its value. It had occurred to him that as M_2 had been greatly overrated by astronomers, the above equation $M_2 = ae_1$ might still hold good. If so, the eclipse might not only be visible at Thebes, but annular; and it was more probable that a *recorded* eclipse should be of an unusual character, as an annular eclipse would be, than an ordinary partial one. The moon being near her apogee, a total eclipse would be impossible. On the possibility of the equation holding good, he desired to ascertain the opinions of the Section.

Description of a Solar Eyepiece invented by the Rev. W. R. Dawes, *F.R.A.S., and constructed, under his direction, by* Dollond. *Communicated by* Dr. Lee.

In the greatly improved form of this eyepiece, as exhibited, the fundamental principle of the original construction is preserved, which consists in greatly contracting the field of view, so that the heat emanating from the portion of the sun's focal image admitted to the eye-glass, however large the telescope may be, shall be less than would cause any injury to the dark glasses which defend the eye from excessive light. The diaphragms by which the field is thus contracted are arranged

in a rotating circular plate, which is prevented from becoming inconveniently heated by a layer of plaster of Paris on its first surface, and by a coating of enamel on the brass plate on which it rotates. The eye-lenses and dark glasses are also arranged in rotating wheels.

By the use of the smallest apertures in the diaphragm-plate, the middle, or *umbra*, of large solar spots may be advantageously scrutinized, all the rest, even the penumbra of the spot itself, being excluded from view. It was in this way that the inventor discovered the irregular illumination and cloudy appearance of the *umbra* (which was previously supposed to be black, and probably the body of the sun itself), and the existence, in most of the larger and more symmetrical spots, of a small well-defined portion in which no light at all could be seen, and to which alone the term *nucleus* (often erroneously applied to the whole of the *umbra*) ought to be restricted. This is the more important, as the inventor has arrived at the conclusion that the existence or non-existence of this entirely black *nucleus* forms an obvious distinction between *two classes* of solar spots, whose origin is of a very different kind.

This eyepiece is also of great utility in several other species of observation; as, *e. g.*, in the scrutiny of minute and delicate portions of the moon's surface, while the eye is relieved by the exclusion of all the rest from the field of view; in observing lunar occultations, and the eclipses of Jupiter's satellites, and in examining the immediate vicinity of planets for faint satellites, and of bright stars for minute companions. The diameters of the apertures in the diaphragm-plate vary from 0·5 to about 0·01 of an inch. As there is some difficulty in cleaning out the smallest of these without injuring it as a point of a fine needle might do, it may be well to mention that the inventor has found the best instrument for this purpose to be a cat's whisker.

On the Lunar "Mare Smythii," the walled Plain "Rosse," the "Percy Mountains," and the newly named Craters, "Phillips," "Wrottesley," "Chevallier," and "Piazzi Smyth." *By* Dr. Lee, *F.R.S.*

The "Mare Smythii" *.—This interesting portion of the moon's surface was first observed with sufficient care, and delineated accurately, by Schröter in 1792, Sept. 30, twenty-two hours after full moon. T. Mayer and Cassini had represented in its locality a long grey streak. Schröter's drawing, in the main, is executed with great fidelity, and represents all the principal features of the Mare, as well as some interesting craters east of it. In this respect, as well as in a portion of the eastern rim, it is closely in accordance with a drawing made by Mr. Birt on the 30th of July, 1863, when the terminator bisected the surface of the Mare. Mr. Birt also had an opportunity, on the 25th of November, 1863, of verifying in almost every particular Schröter's delineation. Schröter designated this extensive lunar plain "Abraham Gotthelf Kästner," and delineated and described two somewhat extensive depressions eastward of the southern part of the Mare. It would appear from Beer and Mädler's large map that these great selenographers had but imperfectly seen this fine Mare, nearly equal in extent to the Mare Crisium, for they describe "Kästner" as extending like a sea from $-2°$ to $-9°$ south latitude; and that it is almost 30 German miles in length, while they make the Mare Crisium 61 German miles long. They give on their map a dark plain even smaller than that described above, and which, from a careful comparison of the drawings now in existence, appears to be the eastern portion only of the southern part of Schröter's "Kästner." Schröter's delineation being thus so considerably reduced by Beer and Mädler, it becomes quite impossible to identify their "Kästner" with the Mare in question. Accordingly when, on August 20th, 1861, it was seen by Mr. Birt in the immediate neighbourhood of the terminator, the observation assumed the character of a discovery; in fact, the mutilation of this fine plain by Beer and Mädler clearly renders the observation of Mr. Birt a *rediscovery* of the true "Kästner" of Schröter, while the position of one of the depressions east of its southern portion is so nearly

* The name "Smythii" is given to this Mare in commemoration of the extensive and valuable labours of the accomplished and gallant admiral, the author of the 'Celestial Cycle.'

similar to that of the "Kästner" of Beer and Mädler as really to have been taken for it. Under these circumstances it becomes highly important to settle the nomenclature in this part of the moon by distinctly designating both formations, the larger the "Mare Smythii," the smaller "Kästner."

The extent of this large plain—fifteen degrees of latitude and as many, if not rather more, of longitude, viz. 5° N. to 9° 30′ S. latitude, and 80° W. to 95° W. (?) longitude—combined with its great similarity to the Mare Crisium, clearly entitle it to rank as a Mare. As it was first discovered and named by Schröter, it may be considered undesirable to disturb the existing nomenclature; and undoubtedly it would be taking an unwarrantable liberty to change the name, if Beer and Mädler had given the dimensions and outlines on their map *as left by Schröter*. As it is, much confusion has arisen. The plain has not been identified with their delineation; a formation eastward of it has been regarded and published as "Kästner;" and the only way now to set the matter right is to distinguish the one from the other unmistakeably. Again, the name of "Kästner" is but little known in this country, and is of mere local interest, while the name of "Smyth," as the Rev. T. W. Webb remarks, "is not merely of English but of universal celebrity." It is therefore proposed to retain the name "Kästner" for the smaller and more ancient formation, and to commemorate the rediscovery by designating the larger and more modern plain by the name of the gallant admiral who has contributed so largely, not only to the advancement of astronomy, but also to the pleasure of every practical astronomer, by the publication of his most interesting 'Cycle.'

The walled plain "Rosse" is situated in the south-east quadrant of the moon's surface. It has hitherto been *unrepresented*, and is one of the largest individualized localities on the lunar disk unappropriated. It was first noticed by Mr. Birt, on November 3, 1862; but its characteristics, boundary-walls, and distinct individual character were determined with the Hartwell equatoreal on the 27th of August, 1863. Its selenographical coordinates are 53° to 60° S. latitude and 48° to 55° E. longitude, and it extends from the craters Zuchius and Segner on the south to Phocylides on the north. Its eastern and western walls are partly interrupted by two small but conspicuous craters, as yet *unnamed*. The surface of this walled plain appears, under a rather advanced illumination, to be very smooth and level, with the exception of a remarkable promontory stretching towards the middle of the enclosure. This walled plain has received the name of "Rosse," in honour of the nobleman who has so liberally contributed to the advancement of astronomy by the erection of one of the largest telescopes in existence at Parsonstown in Ireland.

The "Percy Mountains" are a fine chain, extending from Gassendi to Cavendish, with some very interesting crater-openings on their summits. They have been named to honour the memory of Earl Percy, the late Duke of Northumberland, a well-known patron of astronomy and a munificent donor of refracting telescopes to the Universities of Cambridge and of Durham. They are now under a regular course of observation by Mr. Birt, both with the Hartwell equatoreal and the Royal Society's 4½-inch achromatic, which was lately voted to him by the Council. Selenographical coordinates 17° to 28° S. latitude, and 41° to 53° E. longitude.

"Phillips" and "Wrottesley" are two interesting craters adjoining the magnificent formations "Wilhelm Humboldt" and "Petavius." The occasion of naming them, as well as the discrepancy occurring in Beer and Mädler's map, as compared with "Der Mond," relative to "Wilhelm Humboldt" and "Phillips," are fully detailed in the 'Astronomical Register' for November 1863, pp. 169 and 170. "Phillips," which is nearly the size of Plato, has for its selenographical coordinates 24° to 27° S. latitude, and 75° to 80° W. longitude. It is marked "Humboldt" on Beer and Mädler's map, which is decidedly a mistake. The coordinates of "Wrottesley" are 23° S. latitude and 56° W. longitude.

"Chevallier," named in honour of the distinguished astronomer and scholar, the Rev. Temple Chevallier of the University of Durham, is situated in the north-west quadrant of the moon's disk. Between "Atlas" and "Messala" there are three craters, two of which are unnamed. It is proposed to designate the nearest to "Atlas" "Chevallier"; its selenographical coordinates are 45° N. and 50° W.

The crater "Piazzi Smyth" is named, with the Teneriffe Mountains, to commemorate "An Astronomer's Experiment." It is interestingly situated on a soft

ridge on the surface of the Mare Imbrium, in latitude 42° N. and longitude 3° 30′ E. It is almost the only crater in a somewhat irregular line of detached rocks which are designated the Teneriffe Mountains, the principal of which is the isolated rock "Pico," named by Schröter. These mountains are each designated by a Teneriffan appellation. A fine rock, equal to "Pico," and westward of "Piazzi Smyth," is called "Piton"; those south and north of "Pico," "Guajara" and "Rambleta"; a fine branching chain east of "Rambleta," "Alta Vista"; and a rock N.E. of "Rambleta," "Chajorra."

On the Distribution of Heat on the Sun's Surface, and the Currents in its Atmosphere. By J. J. MURPHY.

Professor Secchi, of Rome, has ascertained that the sun's equator is sensibly hotter than its poles. That this should be the case follows from the meteoric theory of solar heat. The asteroids which revolve round the sun, and fall into its atmosphere as meteors, probably occupy, like the entire solar system, a lenticular space having its greatest diameter nearly coincident with the sun's equator; and if so, a greater number of meteors must fall on the equatorial than on the polar regions of the sun, making the former the hottest. The meteoric theory will also account for the currents in the sun's atmosphere, observed by Mr. Carrington (see the 'Proceedings of the Royal Astronomical Society,' 13th April, 1860). He finds that the spots in the lowest latitudes drift most rapidly from W. to E. Were the sun's atmosphere, like the earth's, acted on by no other motive power than the unequal heating at different latitudes, the relative direction of the currents would be the reverse of this, in virtue of the well-known principles of the trade winds and "counter-trades," and this would be true at all depths in the sun's atmosphere. But if meteors are constantly falling into the sun's atmosphere, moving from west to east with a velocity scarcely less than that of a planet at the sun's surface, and in greatest number in its equatorial regions, there is a motive power which is adequate to drive its atmosphere round it from west to east, and with greatest velocity at the equator. The intensely bright meteor-like bodies which Mr. Carrington and another observer simultaneously saw traverse the sun's disk moved from west to east, and they were almost certainly asteroids falling into the sun.

Researches on the Moon. By Professor PHILLIPS, *F.R.S.*

The author, having on previous occasions presented his views as to the methods and objects of research in the moon, was desirous now to state a few results, and exhibit a few drawings, the fruit of recent examinations of the moon by means of a new equatoreal by Cooke, with an object-glass of 6 inches*. In sketching ring mountains, such as Theophilus and Posidonius, the author has been greatly interested by the changes of aspect which even a small alteration in the angles of elevation and azimuth respectively produce in the shadows and lights. Taking an example from Cyrillus, with its rocky interior, and fixing attention on the nearly central mountain, it always appears in the morning light to have two principal unperforated masses. By a slight change in the direction of the light, the division of these masses is deeply shaded on the north or deeply shaded on the south, and the figure of the masses, *i. e.* the limit of light and shade, seems altered. A slight change in the angle of elevation of the incident light makes more remarkable differences. On Posidonius, which is a low, nearly level plateau, within moderately raised borders, the mid-morning light shows with beautiful distinctness the shield-like disk of the mountain, with narrow broken walls, and in the interior, broad, easy undulations, one large and several smaller craters. In earlier morning more craters appear, and the interior ridges gather to form a broken terrace, subordinate to the principal ridge. This circumstance of an interior broken terrace, under the high main ring of mountain, is very frequent, but it is often concealed by the shadow of the great ridge in early-morning shadows. To see it emerge into half-lights, and finally into distinct digitations and variously directed ridges, as the light falls

* He has also observed the aspect of the sun, but on this subject he reserved his remarks.

at increasing angles, is a very beautiful sight. But it is chiefly to the variations in the central masses of lunar mountains and their physical bearings that the author wishes to direct attention. Many smaller mountains are simply like cups set in saucers, while others contain only one central or several dispersed cups. In Plato is a nearly central very small cup, bright, and giving a distinct shadow on the grey ground, as seen by Mr. Lockyer, Mr. Birt, and Professor Phillips himself. But in the centre of many of the larger mountains, as Copernicus, Gassendi, and Theophilus, is a large mass of broken rocky country, 5000 or 6000 feet high, with buttresses passing off into collateral ridges, or an undulated surface of low ridges and hollows. The most remarkable object of this kind which the author has yet observed with attention is in Theophilus, of which mountain two drawings are given, in which the author places equal confidence, except that the later drawing may have the advantage of more experience. The central mass is seen under powers of 200 to 400 (the best performance is from 200 to 300), and appears as a large conical mass of rocks about fifteen miles in diameter, and divided by deep chasms radiating from the centre. The rock-masses between these deep clefts are bright and shining, and the clefts widen towards the centre; the eastern side is more diversified than the western, and, like the southern side, has long excurrent buttresses. As the light grows on the mountain, point after point of the mass on the eastern side comes out of the shade, and the whole figure resembles an uplifted mass which broke with radiating cracks in the act of elevation. Excepting in steepness, this resembles the theoretical Mont d'Or of De Beaumont; and as there is no mark of cups or craters in this mass of broken ground, the author is disposed to regard its origin as really due to the displacement of a solidified part of the moon's crust. He might be justified by Professor Secchi's drawing of Copernicus in inquiring if the low excurrent buttresses may indicate issues of lava on the southern and western sides? On the whole, the author is confirmed in the opinion he has elsewhere expressed, that on the moon's face are features more strongly marked than on our own globe, which, rightly studied, may lead to a knowledge of volcanic action under grander and simpler conditions than have prevailed on the earth during the period of subaërial volcanos. The author also exhibited a drawing of Aristarchus, showing some undescribed features in the aspect of that, the brightest part of the moon's surface.

On the Changing Colour of the Star 95 *Herculis.*
By Professor PIAZZI SMYTH, *F.R.S., Astronomer Royal for Scotland.*

The star 95 Herculis is a double star, of which the two members are nearly of equal magnitude (about the 5th), and are six seconds apart, in R. A. 17h. 55m. 33s., and N. D. 21° 35′ 56″ epoch 1860. It has hitherto been catalogued as a diversely coloured pair of stars, one member being called "apple-green" and the other "cherry-red." These colours have moreover been looked upon (as are the colours of all ordinary stars) as constant features. Being observed, however, by the author when he was on the Peak of Teneriffe, in 1856, they were found nearly colourless, and without any diversity of tint the one from the other. This observation was considered anomalous at the time, and was so to a certain extent; but, on examining older authorities, the author has met with two other instances of an equality of pale colour being observed in the two components of 95 Herculis—one by Sestini in 1844·50, and the other by Struve in 1832·53; and remarks that, while these two epochs are separated by twelve years exactly to a tenth, the later of them precedes the Teneriffan observation in 1856·58 by almost exactly the same quantity. Now this looks like a regular periodic change, of very short period; and it is not improbable that the twelve years constitutes a multiple of a shorter period still, during which the change of tint of the stars is so marked that, from being merely grey at a certain time, one star has been described as becoming an "astonishingly yellow-green," and the other "an egregious red." Although this is the first instance of this kind yet detected in the sky, the author thinks that it will not be found a solitary one; and that its phenomena may bear some relation to the "eclipse" pink prominences of our sun, and to auroral displays.

On Sun-spots and their Connexion with Planetary Configurations.
By B. Stewart, *F.R.S.*

The author described the results of his examination of a continuous series of pictures of the sun's disk taken by the Kew photoheliograph between February 1862 and August 1863. He remarked that "there is little difficulty in finding approximately, by a comparison of two or three consecutive pictures, at what portion of the sun's disk any spot ceases to increase and begins to wane, or, on the other hand, breaks out into a visible appearance." Now, it appears to be a law almost universal, that if there be several spots, and one decreases before coming to the central vertical line passing through the sun's disk, another spot does the same; if, on the other hand, a spot breaks out on the right half and increases up to the border, another will do the same. The author thinks that he has noticed a connexion between this behaviour of sun-spots and the configuration of the nearer planets, Mercury and Venus, of the following nature. Let us suppose that Mercury and Venus are both in a line considerably to the right of the earth, then spots will decrease as they come round from the left-hand side, and before they reach the centre of the disk. On the other hand, if these two planets are considerably to the left of the earth, there will be a tendency for spots to form on the right half of the disk and to increase up to the border.

Light and Heat.

Account of Preliminary Experiments on Calcescence. By C. K. Akin, *Ph.D.*

In this paper the author described the attempt which he had made, conjointly with Mr. George Griffith, the Assistant General Secretary of the British Association, to carry out some of the experiments proposed by him in his paper "On the Transmutation of Spectral Rays," for the purpose of producing the converse phenomenon of fluorescence, for which the term *calcescence** was suggested to him for adoption. As the experiments, partly from the unfitness of the apparatus employed, and partly from other interruptions, were not brought to a successful issue, and moreover are likely soon to be renewed under more favourable conditions, and with the more powerful and convenient instruments supplied by the liberality of the British Association, a description of the same in print will best be reserved for a future occasion.

On some Phenomena produced by the Refractive Power of the Eye.
By A. Claudet, *F.R.S.*

This paper was to explain several effects of refraction through the eye, one of which is, that objects situated a little behind us are seen as if they were on a straight line from right to left. Another, that the pictures of external objects which are represented on the retina are included in an angle much larger than one-half of the sphere at the centre of which the observer is placed; from this point of view a single glance encompasses a vast and splendid panorama, extending to an angle of 200°. This is the result of the common law of refraction. All the rays of light passing through the cornea to the crystalline lens are more and more refracted in proportion to the angle at which they strike the spherical surface of the cornea. Consequently, the only objects which are seen in their true position are those entering the eye in the direction of the optic axis. By this refraction the rays which enter the eye at an angle of 90° are bent 10°, and appear to come from an angle of 80°. This phenomenon produces a very curious illusion. When we are lighted by the sun, the moon, or any other light, if we endeavour to place our-

* From *calcium*, the name of the characteristic chemical element of lime, whose action on the oxyhydrogen flame most probably represents a phenomenon of the kind alluded to, and has suggested the speculations contained in the paper adverted to in the text.

selves in a line with the light and the shadow of our body, we are surprised to find that the light and the shadow seem not to be connected at all, and that, instead of being in a line, they appear bent to an angle of 160° instead of forming one of 180°; so that we see both the light and the shadow a little before us, where they are not expected to be. The eye refracts the line formed by the ray of light and that formed by the shadow, and the effect is like that of the stick, one-half of which, being immersed in water, appears crooked, or bent into an angle at the point of immersion. This enlargement of the field of vision to an angle of 200° is one of those innumerable and wonderful resources of nature by which the beauty of the effect is increased. By it our attention is called to the various parts of the panorama which appear in any way a desirable point of observation, and we are warned of any danger from objects coming to us in the most oblique direction. These advantages are particularly felt in our crowded towns, where we are obliged to be constantly on the lookout for all that is passing around us.

On Specific Refractive Energy.

By J. H. Gladstone, *Ph.D., F.R.S., and* Rev. T. P. Dale, *M.A., F.R.A.S.*

In a paper laid before the Royal Society a few months ago, the authors came to the conclusion that every liquid is endowed with a certain optical property, which is independent of its temperature, and which accompanies the substance in its mixtures with other liquids, and to a certain extent in its chemical combinations.

This property is the refractive index, minus unity, divided by the density $\frac{\mu-1}{D}=C$, and for this constant the authors have suggested the term 'specific refractive energy.' It is not maintained that the above formula represents the property with perfect accuracy, for each observed refractive index is affected by dispersion, which does not follow the same law; and even if the refraction of the theoretical limit of the spectrum be taken, $\frac{\nu-1}{D}$, there is apparently some disturbing cause of a higher order which still remains unaccounted for. Other physicists have sought for this property in what Newton called the absolute refractive power, $\frac{\mu^2-1}{D}$, but this does not agree so well with the experimental observations.

The authors now proposed to show how nearly the expression $\frac{\mu-1}{D}$ represents the real law as determined from observation, and under what varied circumstances it may be applied, and also to suggest a possible cause of its divergence from absolute coincidence. In doing so they referred not merely to experiments of their own, but also to those of Dulong, Jamin, and Le Roux on the refraction of gases and vapours, and to other determinations by Brewster, Deville, Weiss, and Schraub.

1. *Specific refractive energy and change of volume by heat.*—It was shown in the paper above referred to that the specific refractive energy of a liquid, $\frac{\mu-1}{D}$, (or if ν represent the theoretical limit of the index, $\frac{\nu-1}{D}$,) is a constant, or very nearly so, at all temperatures. Yet in almost every instance examined it was found that the specific refractive energy slightly diminished as the temperature increased. The exceptions are quite within the limits of errors of experiment, and may probably be thus accounted for.

2. *Specific refractive energy and change of volume by pressure.*—The single experiment on this subject made by Jamin on water gave a result which is about equally accordant with theory, whether, with that observer, we calculate it by $\frac{\mu^2-1}{D}$, or prefer the formula $\frac{\mu-1}{D}$.

3. *Specific refractive energy and change of aggregate condition.*—It has been shown in previous papers that the refractive energies of water and phosphorus in the liquid

and solid condition vary directly as their densities. This observation is now extended to other bodies and to the gaseous condition.

Condition.	Water.	Phosphorus.	Sulphur.	Bisulph. Carb.	Ether.
Solid	·336	·58	·50	...	...
Liquid	·333	·59	·49	·49	·49
Gaseous	·321	·50?	·49?	·44	·46
Calculation from constituents	·339	...	...	·48	·53

In the above table the density of water at 0° C. is taken as unity throughout. It will be observed that the specific refractive energies of the solid and liquid condition are almost identical, and that those of a gas are somewhat less, with one doubtful exception, sulphur. As these are taken for the most luminous part of the spectrum, the disturbance caused by dispersion, at least, will make itself felt; and it is worthy of remark that (setting aside sulphur) the more dispersive a substance is, the greater is the difference between its specific refractive energy in the liquid and gaseous condition.

There is no resemblance between the absolute refractive powers of a substance in these two states, as was observed long since by Arago.

4. *Specific refractive energy and solution.*—It was laid down in a former paper as approximately true that the specific refractive energy of a mixture of two liquids is the mean of the specific refractive energies of its constituents. The following observations on solutions of two gases, two liquids, and two solids in water will serve to test whether this law can be extended to solution in general, even where there is a change of aggregate condition in one of the bodies, or where a feeble chemical affinity exists between the two. The specific refractive energy of water is taken at ·3285 for Fraunhofer's line A, and ·333 for the line D.

Substance.	Specific refractive energy.	Specific refractive energy of solution in water.	
		Observed.	Calculated.
Ammonia	·506	·375	·378
Hydrochloric acid	·277	·344	·316
Alcohol	·456	·396	·395
Nitric acid	·289	·310	·311
Sugar	·340	·340	·3365
Common salt . .	·260	·318	·315

In all these cases the observed and the calculated numbers are nearly coincident, with the exception of hydrochloric acid, where the combination of the gas with water seems to have materially altered its optical property. It is so likewise with sulphuric acid.

The above-mentioned solution of sugar in water, when mixed with an equal weight of water, gave the specific refractive energy ·337, instead of ·3365, which may be taken as the same thing.

The doubly refracting crystals of tartaric acid gave as their specific refractive power, deduced from the mean of the two spectra, ·319 for the line A, and a solution in water gave ·316—a lower, instead of ·324, a higher number, as the theory requires.

It may be a matter for consideration how far the molecular forces that cause crystallization, or maintain a body in a solid or liquid state, influence the velocity with which light is propagated through the medium.

5. *Specific refractive energy and chemical combination.*—Dulong showed long ago that the absolute refractive power of a compound gas is nearly, but not exactly, the mean of the specific refractive powers of its gaseous constituents. This is equally true of the specific refractive energy. But the observation need not be confined to gases. In the following table the actual specific refractive energies of three liquids is compared with the mean of the specific refractive energies of their constituents, whether gaseous, liquid, or solid.

	Brom. Phosph.	Chlor. Phosph.	Chlor. Carb.
Observed	·237	·348	·287
Calculated from constituents . . .	·250	·304	·264

These show merely a general resemblance between the observed and the calculated energies. They form part of the ever-multiplying proofs, that though a chemical compound may be considered as having a specific refractive energy composed of the specific refractive energies of its component elements, it is, as stated elsewhere, modified by the manner of combination.

The specific refractive energy of chloride of ammonium appears to be ·42. As calculated from Dulong's numbers for nitrogen, hydrogen, and chlorine gases, it should be only ·34; but as calculated from the specific refractive indices of ammonia and hydrochloric acid when liquefied by solution, it is ·417.

On a New Form of Syren. *By* W. Ladd.

A disk of cardboard is perforated with 1682 holes, apportioned into twenty-four concentric circles, the fifteen interior ones being divided into regular, and the remainder into irregular, intervals. The former are divided in the following proportions:—For every two holes in the first circle (counting from the centre) there are 3 in the 2nd, 4 in the 3rd, 5 in the 4th, 6 in the 5th, 8 in the 6th, 10 in the 7th, 12 in the 8th, 16 in the 9th, 20 in the 10th, 24 in the 11th, 32 in the 12th, 40 in the 13th, 48 in the 14th, and 64 in the 15th. If with a small tube air is blown into these circles whilst the disk is in rapid rotation, a series of musical notes will be obtained, allied to each other in the relative proportion of the numbers. Looking at the outer portion of the disk, lines of holes are observed radiating from the centre, and dividing the disk into 24 equal parts; and, if the other holes were stopped, each of these rings would produce a single sound, the same as the 6th row of the inner series. This note will form the fundamental of all the harmonies. If a point is taken in the first of the external rings, and, starting from it, with a pair of compasses the distance between it and the first intermediate hole is repeated five times, it will correspond with four of the fundamental spaces; and if a single jet of air is forced through these holes whilst the disk is rotating, the idea conveyed to the mind will be precisely the same as if two separate notes were sounded together—the two notes being a fundamental and its third, the proportions of the vibrations being as 5 : 4. The 2nd row is divided in the ratio of 4 : 3—this will give a fundamental and its 4th (or subdominant); the 3rd row is divided as 3 : 2, giving the fundamental and its fifth (or dominant); the 4th row, divided as 5 : 3, gives a fundamental and its 6th; the 5th row is as 7 : 4—this giving a fundamental and flat 7th; the 6th row has a combination of four holes, in the proportion of 6 : 5 : 4 : 3—this will give a perfect chord of four notes; the 7th row has four holes, in the proportion of 8 : 6 : 5 : 4—this will give a perfect chord with octave of the fundamental; the 8th row is divided in the proportion of 5 : 4 : 3, giving a perfect major triad with inverted 5th; and the last row is divided in the proportion of 6 : 5 : 4, which forms a perfect major triad. The exact intonation of the notes given out by the inner circles, and the exquisite harmonies produced by the outer ones, are remarkable.

M. Soleil's *Tenebroscope, for illustrating the Invisibility of Light. Exhibited and described by the* Abbé Moigno.

The instrument exhibited consisted of a tube with an opening at one end to be looked into, the other end closed, the inside well blackened, and a wide opening across the tube to admit strong light to pass only across. On looking in, all is perfectly dark, but a small trigger raises at pleasure a small ivory ball into the course of the rays, and its presence instantly reveals the existence of the crossing beam by reflecting a portion of its light.

On a New Micrometer. By M. H. Soleil ; *exhibited and explained by the* Abbé Moigno.

This consisted of two Ramsden's eyepieces, one fixed near the object or image to be measured, the other moveable to suit the vision of the observer, with a ruled glass micrometer-plate placed between them. The magnifying power of this eyepiece being ascertained by a comparison of the object as seen directly, with the same object as seen through the micrometer, it then became applicable to the telescope, the microscope, and even to goniometry by a certain adjustment, and having the plate to which the objective eyepiece was attached graduated on its circumference.

On Spectral Analysis. By Prof. Plücker.

It is generally admitted now, that every gaseous body rendered luminous by heat or electricity sends out a peculiar light, which, if examined by the prism, gives a well-defined and characteristic spectrum. By such a spectrum, by any one of its brilliant lines whose position has been measured, you may recognize the examined gas. This way of proceeding constitutes what is called spectral analysis, to which we owe, already, the discovery of three new elementary bodies. In order to give to spectral analysis a true and certain basis, you want the spectrum of each elementary substance. Very recently, some eminent philosophers, in examining such spectra, met with unexpected difficulties, and doubts arose in their minds against the new doctrine. Those doubts are unfounded. The fact is, that the molecular constitution of gases is much more complicated than it has been generally admitted to be till now. The spectra therefore, always indicating the molecular constitution of gases, must also be more complicated than they were at first thought to be. By these considerations, a new importance, of a physical nature, is given to spectral analysis. You may recognize by the spectrum of a gas, not only the chemical nature of the gas, but you may also obtain indications of its more intimate molecular structure—quite a new branch of science. Allow me now to select, out of the results already obtained, two instances only. Let me try to give what I may call the history of the spectra of two elementary bodies—of sulphur and nitrogen. In order to analyze by the prism the beautiful light produced by the electric current if it pass through a rarefied gas, I gave to the tube in which the gas is included such a form that its middle part was capillary. Thus I got within this part of the tube a brilliant film of light, extremely fitted to be examined by the prism. The date of my first paper on this subject is the 12th of March, 1858. About a year ago, after having provided myself with apparatus more suited to my purpose, I asked my friend Professor Hittorf, of Münster, to join me in taking up my former researches. The very first results we obtained in operating on gases of a greater density opened to us an immense field of new investigation. We found that the very same elementary substance may have two, even three, absolutely different spectra, which only depend on temperature. In our experiments we made use of Ruhmkorff's induction-coil, whose discharge was sent through our spectral tubes. In order to increase at other times the heating-power of the discharge, we made use of a Leyden jar. Now, let us suppose a spectral tube, most highly exhausted by Geissler's mercury-pump, contains a very small quantity of sulphur. The discharge of the coil will not pass through the tube if it do not meet with ponderable matter, either taken from the surface of the glass or, if the discharge be very strong, by the chemical decomposition of the glass. In heating the tube slowly by means of a lamp, in order to transform a part of the sulphur into vapour, all accidental spectrum, if there be one, will disappear, and you will get a pure and beautiful spectrum of sulphur. I suppose the Leyden jar not to have been interposed. If you now interpose it, the spectrum just spoken of will suddenly be replaced by quite a different one. We were, generally, led to distinguish two quite different classes of spectra. Spectra of the first class consist in a certain number of bands, variously shadowed by dark transversal lines. Spectra of the second class consist in a great number of most brilliant lines on a dark ground. Accordingly, sulphur has one spectrum of the first class and another one of the second class. You may, as often as you like, obtain each of these two spectra. In operating on a spectral tube containing

nitrogen at a tension of about 50 millimètres, you will, without the Leyden jar, get a most beautiful spectrum of the first class. After interposing the jar, a splendid spectrum of the second class will be seen. But here the case is more complicated still. The above-mentioned spectrum of the first class is not a simple one, but it is produced by the superposition of two spectra of the same class. Ignited nitrogen, at the lowest temperature, has a most beautiful colour of gold. When its temperature rises, its colour suddenly changes into blue. In the first case, the corresponding spectrum is formed by the less refracted bands extended towards the violet part; in the second case, it is formed by the more refracted band of the spectrum extended towards the red. Nitrogen, therefore, has two spectra of the first class and one spectrum of the second class. The final conclusion, therefore, is that sulphur has two, nitrogen three, different allotropic states. It may appear very strange that a gaseous body may have different allotropic states, *i. e.* different states of molecular equilibrium. It may not appear, perhaps, more strange that a substance, hitherto supposed to be an elementary one, may really be decomposed at an extremely high temperature. From spectral analysis there cannot be taken any objection that sulphur and nitrogen may be decomposed. Chloride of zinc (or cadmium), for instance, exhibits two different spectra. If heated like sulphur, and then ignited by the discharge of Ruhmkorff's coil, you will get a beautiful spectrum either of chlorine or of the metal, if either the Leyden jar be not interposed or be interposed. There is, in this case, a dissociation of the elements of the composed body in the highest temperature, and recomposition again at a lower temperature. You may consider the dissociation as an allotropic state, and, therefore, I may make use of this term as long as the decomposition be not proved by the separated elements.

*On the Focal Adjustment of the Eye**. *By* Barnard S. Proctor.

The object of the paper was to afford answers to the following questions:—

Is it occasionally, generally, or universally that the human eye has distinct foci for vertical and horizontal lines?

Is the power of altering the focus of the eye exceptional or general? and what is the extent of the change?

Can eyes, having distinct vertical and horizontal foci, be made to adjust these foci to any particular distance at the same time?

Have the two eyes generally different focal lengths?

Does a good resolving power always accompany a good adjusting power?

Are markings on a flat surface resolved better by one eye or both?

What is the appearance of a vertical line, and what of a horizontal line and a point, when within or beyond focus?

Do the powers of the eye vary much with time of day, bodily or mental fatigue, &c.?

For experimenting upon the focus, an object was constructed consisting of a darkened glass, upon which were scratched lines so as to transmit light. The design adopted was a cross consisting of fine double lines, simple appliances being adopted for transmitting through these lines a constant amount of light, and for varying the distance between the object and the eye of the observer. For ascertaining the resolving power of the eye, a test-object was constructed in the same manner, the design upon it consisting of two lines diverging at a very acute angle from a point, and bearing an index showing how many thousandths of an inch space there was between the lines at the point where the observer ceased to have the power of distinguishing them as two lines.

This test-object, and the same mode of using it, was adopted in experimenting upon the power of various eyes to change focus: the resolving power having been ascertained for the shortest comfortable focus, the same was tried for double and three times the distance.

In all these experiments, the person whose sight was being examined did not know the measurements till the conclusion of the experiments; thus was avoided

* The entire paper is printed in the Philosophical Magazine for October 1863.

any tendency which there might have been to fancy that at double the distance double the width of the lines was requisite to admit of resolution.

As the result of the examination of the sight of nine individuals, it was found that seven have equal focus for both eyes; four have longer focus for vertica lines than for horizontal; two have shorter focus for vertical, and three have equal foci for both. Of seven observers, six have the power of varying the focus for both horizontal and vertical lines. All have the power of bringing both lines into focusl at once. Of nine observers, four have the best resolving power for horizontal lines, one for vertical, and four equally good for either; the better resolving power generally coinciding with the shorter focus.

Theoretically, at double the distance double the space between lines should be required to admit of their resolution. In most instances it was found, by experiment, that less than double the space was required at double the distance—a fact resulting probably from the aberrations varying with the adjustment, as the results of the observations were only taken account of when the observer believed the focal adjustment to be accurate. It was found that in using two eyes we generally have results corresponding with the powers of our best eye. Different observers describe the appearance of a line out of focus in various manners, as follows:—a faint band but with clear edges; a line with misty edges; a band consisting of two or more misty lines, sometimes nearly clear, and not constant in number—the motions of the eyelid will frequently alter the number.

The evidence regarding the variation of sight before and after breakfast was conflicting; but all agreed that bodily or mental fatigue very much impaired both the resolving and adjusting powers.

On a new kind of Miniature possessing apparent Solidity by means of a Combination of Prisms. *By* H. Swan.

By this invention is obtained a miniature representation of the human form or other objects possessing the appearance of perfect solidity, the image being apparently imbedded in the thickness of a small enclosed block of glass or crystal, thereby defining form and expression with a degree of accuracy unattainable in a flat portrait. This is effected by a new application of the principles of binocular vision employed in the ordinary stereoscope. A stereoscopic pair of transparent pictures (taken at an angle suitable for the effect intended) are produced by the ordinary photographic means. To effect the combination of these, the block of glass or quadrangular prism, in the interior of which the solid image is to appear, is composed of two rectangular prisms ground to an angle of about 39° or 40°. These are placed together so as to form one solid quadrangular prism, divided lengthwise by a thin film of air. If one of the pictures be now placed at the back of this combination, and the other picture at the side, on attempting to look through the combination the two images will be superposed on each other (forming one solid image, apparently imbedded in the crystal), all the rays which fall on one side of a line perpendicular to the surface of the prism next the eye suffering total reflexion at the inner oblique surface of that prism, while nearly all those rays which fall on the other side of this line will be transmitted, unaltered in direction, through the body of the combination. Thus, one of the eyes perceives only the object at the back of the prisms, while to the other eye the picture at the side is alone visible, and that lying apparently at the back also, producing the perfect appearance of solidity. It is evident that, to produce these results, care must be taken not only that the pictures are not misplaced so as to produce the pseudoscopic effect, but also that the picture which suffers reflexion shall be reverted to compensate for the reversion occasioned in reflexion.

On the Elasticity of the Vapour of Sulphuric Acid. *By* T. Tate*.

The author gave general formulæ (derived from the results of his experiments) expressing the law connecting the pressure and temperature of the vapours of sulphuric acid diluted with different equivalents of water.

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* The paper is printed in Phil. Mag. Dec. 1863.

Electricity, Magnetism.

On Bonelli's Printing Telegraph. By W. Cook.

The author remarked upon the simplicity, regularity, and economy of time which Bonelli's system offers as compared with others. Independence of synchronic movement or elaborate clock-work, freedom from all delicacy in the mechanical detail, and the substitution of the most absolute simplicity in the place of that which, until now, demanded a special knowledge to keep the machines in working order, are among the practical advantages obtained; while, on the other hand, rapidity and certainty, never even hoped for, are ensured. The principal features of the new system are two tables in cast iron, placed inversely to each other at the corresponding stations, and each provided with a miniature railway, over which run two waggons, one carrying the type-set message, the other the paper, chemically prepared with nitrate of manganese, and two combs, formed by the extremities of the wires of the line, one of which touches the type at one station, while the other passes over the prepared paper at the other; a spring catch to each of the waggons setting them free to move by the closing of an electrical current. Neither on short circuit nor at a distance has the slightest difficulty in working the Bonelli machine been experienced, a well-considered system of counter-currents having completely annihilated the inconveniences which, from the time of Bain to the present moment, have been inevitable in electrochemical telegraphy.

On a Printing Telegraph. By D. E. Hughes.

This instrument requires but one electrical wave for each letter, whereas for the "Morse" an average of four waves is required for each letter, and the dial instrument requires seven. There are twenty-eight keys, like the keys of a piano, each corresponding to a letter or mark—as (say) a full-stop or a number—at pleasure. When one of the keys corresponding to a letter is depressed, this brings a detent in contact with a pin corresponding to that letter on the circumference of a uniformly revolving type-wheel, stops it, and at the same time sends an electric wave to the distant station, which, by an electro-magnet detaching a similar detent, stops the same letter for the instant, and, by a revolving cam brought up, presses the paper against the type, the impression of which is thus taken at the distant station. The rising of the detent by the key rising to its place simultaneously stops the electric current, and each wheel again starts into motion at the same letter, as they had each been stopped exactly at the same letter; and so letter after letter is printed nearly as fast as the keys of a pianoforte can be moved. The chief mechanical feature of this machine is the almost mathematical synchronism of the two type-wheels, continuously revolving—one at the transmitting, the other at the distant receiving station—any little difference that may accidentally occur being corrected by the machine itself; this exact synchronism between the two type-wheels is absolutely necessary. Approximate synchronism is obtained by the adjustment of two vibrating springs in unison—the perfect synchronism being obtained by a small correction, produced, as each letter is printed, by the very act of printing. The type-wheel is either hastened or retarded, as may be required, to bring the letter truly opposite the printing-pad. The means by which the machine corrects itself at each letter, or at the commencement of work, is by means of a correcting cam—a solid wedge, pushed down into a similar hollow wedge—one on the driving part, the other on the arbour of the wheel. The paper to be printed on is coiled on a reel, and is drawn forward by the machine, and pressed up against the letter to be printed by the electric wave that brings the required letter or number to its place at the under side of the revolving wheel. A special value in working submarine cables is claimed for this instrument, the following rates of speed having been obtained in different lengths:—

Atlantic cable..............	2500 miles,	4 words per minute.
Red Sea cable	2000 „	6 „
„ „	1000 „	10 „
„ „	500 „	24 „

On an Acoustic Telegraph. *By* W. Ladd.

This instrument consists essentially of two distinct pieces of apparatus. That for transmitting the signal has a small mouth-piece. On the right-hand side there is a finger-key, forming part of the circuit, and an electro-magnet, with a vibrating armature and binding-screw to connect with one of the line wires. Within a case, under a glass cover, is an elastic membrane, in the centre of which is fixed a platinum plate in connexion with the finger-key. A light piece of angular metal, resting on three pins, is so placed that the pin at the angle rests on the plate in the centre of the membrane, the other two resting in cups on its edge, so as to allow of free motion on the points. In the body of the receiver-box is suspended a soft iron core, surrounded by a coil of silk-covered wire, one end of which is in connexion with the finger-key and the other with the binding-screw. The method of producing sound in the receiving instrument depends upon the fact that, at the moment of magnetizing or demagnetizing a piece of iron, there is an alteration in the arrangement of the particles, which gives rise to a slight ticking noise. Having connected the transmitter, by means of an insulated wire, with the receiver, and the binding-screws having been brought in connexion with a battery of three or four elements, if the finger-key on the transmitter be pressed, the person at the receiving-station hears the ticking noise. To convey a musical note or sound, the operator places his mouth to the tube in front of the instrument and sings a note, when immediately the membrane begins vibrating in accordance with the note sounded, and at each vibration breaks contact between the pin and plate in its centre. This, forming part of the circuit, causes the iron core in the receiving instrument to be magnetized and demagnetized a number of times equal to the number of vibrations of the membrane, and so conveys to the receiver an impression of a musical sound. The finger-keys and small magnet at the sides of the instruments are for the purpose of varying the methods of communication by the combination of single sounds, and can also be used with the other parts for the purpose of regulating the lengths of the notes and dividing them into varying portions, so as to form a sound-alphabet somewhat similar to the signals written by Morse's telegraph.

An Electromotive Engine, exhibited and described by W. Ladd.

The electromotive machine exhibited and described by the author consisted of two coils forming a powerful electro-magnet, revolving on an axis parallel to the axes of these coils, and at equal distances between them. On the stand four pillars, forming coils, were planted in the circumference of a circle round the revolving electro-magnet, and at such a distance from it as just to permit its free motion. By a simple contrivance, similar to the commutator, the electric current was so transmitted and reversed as to make each of the pillar-coils a magnet, with the pole it presented to that of the revolving coil as it approached it, of the opposite name, south or north; but the instant it passed, reversing it into one of the same name: thus, while advancing it is attracted; but the instant it begins to retire, repelled; and so a constant motive force is applied to keep it revolving. The engine exhibited was mounted with bevel wheels, carrying an axle, on which a cord could wind up a weight of some pounds. It was also furnished with a friction-break, by which its power (which was, even with only two Grove's cells, considerable) could be exactly measured.

On Galvanic Copper and its Applications. *By* M. Oudry. *Communicated by the* Abbé Moigno.

M. Oudry, having been commanded by the Emperor to endeavour to protect some of the public monuments of France and *chefs-d'œuvre* of art by the electro-plating process, found insurmountable difficulties in depositing a uniform and brilliant coat of copper on iron, either malleable or cast; but having succeeded by mechanical means in reducing electrotype plates of copper to a completely impalpable powder, he used this as a paint, with a medium the basis of which was benzoin instead of linseed oil or any of the oils used with ordinary paints. He had completely suc-

ceeded in giving a surface of a very durable character and of a brilliant, bronzed appearance to iron, plaster, and other objects which it was desirable to protect with this substance.

On Specimens of Telegraphic Facsimiles, produced by Casselli's *Method. Exhibited and explained by the* Abbé Moigno.

M. Casselli adopts Mr. Bakewell's principle, but causes the two cylinders to move at the two stations synchronously, by mechanical means contrived by himself. The copies exhibited by the Abbé were exact facsimiles of the originals, some being pictures, some pieces of music, and some written.

Meteorology, etc.

On the System of Forecasting the Weather pursued in Holland. By Professor Buys-Ballot, *Director of the Royal Netherlands Meteorological Institute.*

In the plan pursued in Holland, observations are taken at four principal places—Helder, Groningen, Flushing, and Maestricht. On the indications afforded at these places the forecasts are based. The author remarked :—"For every day of the year, and for every hour of the day, I have very carefully determined the height of the barometer in the place of observation at that height above the sea where it is suspended. This is a cardinal point not sufficiently observed in England, and not at all in France. The difference of an observed pressure from that calculated on, I call the departure of the pressure—positive when the pressure is greater, negative when it is less. Those departures, besides the observations of the other instruments, are communicated from post to post. The rule is now very simple. If the departures are greater (more positive) in the southern places than in the northern, greater at Maestricht or Flushing than at Groningen or Helder, the wind will have a W. in its name; when the departures are greater in the northern places, the wind will have an E. in its name. More accurately, you may say, the wind will be nearly at right angles with the direction of the greatest difference of pressures. When you place yourself in the direction of the wind (or in the direction of the electric current), you will have at your left the least atmospheric pressure (or the north pole of the magnet). When the difference of pressure of the southern places above the northern is not above four millimetres, there will be no wind of a force above 30 lbs. on the square metre. Moreover, the greatest amount of rain will fall when the departures are negative; and, at the places where the departures are most negative, there also the force of the wind will be generally stronger. Moreover, there will be no thunder if the barometric pressure is not less than two millimetres above the average height, and when at the same time the difference of the departures of temperature is considerable. These rules, and especially the first two, were laid down by me in 1857, in the 'Comptes Rendus'; and on the 1st of June, 1860, the first telegraphic warning by order of the Department of the Interior was given in Holland. It was unfortunate that those telegraphic warnings were not introduced four days sooner, for in that case the first communication would have been a first warning against the fearful storm of May 28, 1860, called the Finsterstorm. All of you know how amply Admiral FitzRoy has arranged the telegraphic warnings all over England. The rules used in Holland have answered well, as is shown in the translation of a paper of Mr. Klein, captain of a merchant-ship, whereto I have added my observations and signals compared with the signals of Admiral FitzRoy. My own paper dates from June 1, 1860, and is extracted by Mr. Klein; but I preferred that the less complete and precise paper of a practical man should be translated, because I thought that the seamen would put more reliance on it. From the tables added to that translation, it appears that I have warned from my four stations just as Admiral FitzRoy has done from his twenty. It must, however, be recorded that, besides those four stations, there are also some stations—Paris, Havre, Brest, in France, and Hartlepool, Yarmouth, Portsmouth, Plymouth,

in England—that send me their observations. Generally they arrive too late; and therefore they throw very little light on the forecasting". . . . . . The author remarked that, for the future, "the normal heights of barometric pressure, or, better, of the barometers which are read, must be conscientiously taken; the observation must be made at more points once a day, and mutually communicated; and at days when there are greatly different departures—that is to say, of three millimetres—or when there is change of inclination, there must be sent a message at noon or in the evening of the same day. In all cases, not only the pressure in the morning, but likewise that at night should be given. A critical indication is when on the previous day the northern stations had greater departures, and on the following day the southern had greater departures, even when the difference in the latter case was small. A caution should be given when the difference of the departures is four millimetres."

Description of an Instrument for ascertaining the Height of a Cloud. *By* Professor Chevallier.

This little instrument consists of two horizontal jointed rulers, graduated from the centre of the joint, the unit of graduation being the length of an upright sliding-piece, moveable upon either of the rulers. One branch of the rulers is directed towards the shadow of a cloud, the horizontal distance of which shadow from the place of observation can be ascertained; and the other branch, carrying the vertical sliding-piece, is directed towards a vertical line drawn through the point of the cloud which casts the shadow. The sliding-piece being now moved along the ruler till the shadow of its inner edge just touches the inner edge of the other horizontal ruler, we have on the ruler and sliding-piece an exact miniature representation of the known horizontal distance of the shadow from the observer (s), and the height of the cloud (h) above the horizontal plane on which the shadow falls.

Hence if d is the number of the divisions on the scale, and 1 the length of the sliding-piece, we have the proportion

$$s : h :: d : 1,$$

whence

$$h = \frac{s}{d}.$$

On the Path of a Meteoric Fireball relatively to the Earth's Surface. *By* Professor Coffin, *of Lafayette College, Eastern Pennsylvania.*

This meteor passed over the northern part of America on the 20th July, 1860, and was observed by different observers over a course of about 1000 miles. It was first seen at an elevation of 92 miles, then at 56 miles, and still lower afterwards at 39 miles. Its orbit appeared to be hyperbolic, and the paper described the various phenomena observed at the different stages of its progress until it traversed the distance of 500 miles over the sea.

On Fogs. *By* J. H. Gladstone, *Ph.D., F.R.S.*

The author had obtained additional returns of the occurrence of fog at different stations round the coasts of the United Kingdom; and on examining these with those previously brought before the notice of the British Association, he had been led to some new generalizations. The most important of these are—

1st. *The distinction between general and local fogs.*—A general fog is found to occur at every or almost every station along a whole country-side, extending usually one or two hundred miles, and often much more than that; while a local fog is marked at only one station, or perhaps at two very near together. There is nothing intermediate between these two kinds of fog; they do not pass insensibly one into the other; there is scarcely any record, in fact, of a fog visiting three or four stations and no more. Local fogs depend, no doubt, on peculiarities of the locality; but it is difficult to draw just conclusions about them, as the peculiarities of the observer seriously affect the returns of them, and there is little or no check. A general fog, on the contrary, is at once recognized by the uniform occurrence of the same date in the lists. The fogs observed at the light-vessels at sea appear

to be almost exclusively of this general character, probably because there are fewer conditions at sea to create a fog over a limited area. The most extensive fog which the author had traced was that of June 22nd and 23rd, 1861; it spread all round England and Wales, except part of the Suffolk and Norfolk coast, all round Scotland, with the exception of some places in the extreme north, and rather irregularly along the whole coast of Ireland.

2nd. *These general fogs are in the habit of visiting certain geographical areas.*—There seem indeed to be certain parts of the coast that are peculiarly liable to become the landfall of a fog, which, according to its magnitude, stretches to a greater or a less distance right and left of this particular spot. Thus, in Ireland, from the lighthouses of which the author possesses daily returns for three years, there are two special localities on which fogs seem to be in the habit of striking. One of these is the south-east corner, often the centre of a fog that covers the coasts of Wexford and its neighbourhood, and sometimes obscures the whole southern and eastern shores. The other is the western half of the southern shore, the fog rarely extending on the one side beyond Minehead, or on the other side beyond Valencia, except that it seems in the habit of visiting at the same time the prominences of Mayo. The northern and the north-west shore was very rarely visited by fogs of any extent. From England and Scotland the author has similar daily returns for only the first half of 1861; and thus he has less confidence in any generalization for these countries, especially as the Irish returns show that these fogs visit a particular coast very unequally in different seasons. Yet, during the period above mentioned, it is perfectly clear that fogs frequently made a landfall of the Suffolk coast, extending perhaps from the north-eastern bend of Norfolk down to Essex, appearing at all the numerous lightships and the principal lighthouses along that side of the country. The most extensive fogs of the eastern coast seemed to have their centre about Yorkshire, from which they stretched north and south, sometimes confined between Northumberland and Lincolnshire, but at other times extending from Aberdeenshire down to Suffolk, and reappearing again at the Forelands. In more than one instance also these fogs crossed the mainland and made their appearance in the Bristol Channel. On the western coast there occurred also several general fogs, their landfalls being the headlands of Wales and Cornwall; they generally penetrated into the Bristol Channel, and got round to the south as far as the Start. Between that point and Beachy Head there were few general fogs in the first half of 1861, though at some stations local fogs abounded. On the eastern coast, the mouth of the Thames escaped their visitation better than any other part.

As to Scotland, the eastern fogs that stretched from England up to the corner of Aberdeenshire sometimes included the whole eastern shores up to the Shetlands in their range. The Orkneys seem to be included in two great areas of eastern and western fogs, the western extending thence by Cape Wrath to the Hebrides and the Western Islands.

It would be at once interesting to the scientific man and useful to the navigator to ascertain more accurately the limits of the areas peculiarly exposed to general fogs, and to determine the meteorological conditions on which the formation, continuance, and disappearance of these fogs depend. Beyond showing in some cases a connexion between the Yorkshire fogs and a north-east wind, the author has done little towards the solution of this problem; but he proposed it as an important inquiry to those scientific men who make meteorology their more especial study.

On Ozone and Ozone Tests. *By* E. J. Lowe, *F.R.A.S., F.L.S., F.G.S., &c.*

The present paper is a continuation of one read last year on "the necessary precautions in ozone observations," and on "certain requisite corrections" before the actual amount of ozone can be determined. A discussion as regards the sensibility of the tests, in which Professor Miller, Dr. Moffat, Mr. M. Lyte, and others took part, induced me to carefully consider this portion of the subject. It struck me that the tests of Schönbein and Moffat must be incorrect, because they were made with the starch of commerce; and as, in the ordinary manufacture of starch, lime, sulphuric acid, and chlorine were used, ordinary starch could not be pure enough

for delicate tests; indeed, chlorine and also lime in combination with sulphuric acid have each the power of staining the preparation of starch and iodide of potassium. Ordinary iodide of potassium is often impure, and the material itself (generally writing-paper) is far from being chemically pure. There has also been a want of uniformity in the proportions of starch and iodide of potassium employed by different observers; in fact, the following are the formulæ:—

Formula of Schönbein, 10 parts of starch to 1 of iodide of potassium.
Formula of Moffat, $2\frac{1}{2}$ parts of starch to 1 of iodide of potassium.
Formula of Lowe, 5 parts of starch (wheat) to 1 of iodide of potassium.

I determined upon manufacturing the starch myself without the aid of the usual chemicals, simply steeping the solutions in distilled water, which was repeatedly changed until *pure* starch alone remained. Starch was made from wheat, rice, sago, arrowroot, potato, arum, snowdrop, crocus, narcissus, tulip, and hyacinth, which were as pure as possible and as white as snow. To Mr. Squire, of Oxford Street, was entrusted the manufacture of pure iodide of potassium, part prepared with water, and part crystallized several times from alcohol. The materials used were calico, specially prepared by Mr. Joseph Sidebotham, of the Strine Works, and a chemically pure photographic paper as well as a very porous paper. There was great difficulty in getting a chemically pure paper, as nearly all were worthless for these experiments. At the recommendation of Dr. R. D. Thomson, 15 grains of prepared chalk were added to each ounce of air-dried starch to prevent sourness. This precaution is requisite for uniformity of effect, as the intensity of action depends upon the amount of water contained in the starch. Thus,—

Tests made with air-dried starch became coloured with five minutes' exposure.
Tests made with starch dried by fire-heat for one minute coloured with seven minutes' exposure.
Tests made with starch dried by fire-heat for three minutes coloured with nine minutes' exposure.
Tests made with starch dried by fire-heat for ten minutes coloured with thirteen minutes' exposure.
Tests made with starch dried by fire-heat for thirty minutes coloured with twenty minutes' exposure.
Tests made with air-dried starch, with chalk added, coloured with twenty minutes' exposure.

Having so far succeeded, I next tried a mixture of 10 parts of starch to 1 of iodide of potassium as a *dry-powder test*; ten minutes' exposure in the open air showed that the powder tests were a success, being more sensitive than the test-slips.

My next determination was with regard to a proper formula, *i. e.* what strength would colour quickest. Powders of different strengths were prepared, varying in the proportion of iodide of potassium and *wheat*-starch, beginning with equal portions of each, and extending as far as 30 parts of starch to 1 of iodide of potassium. It was found that 1 part of iodide of potassium to 5 of wheat-starch was invariably the darkest, the degree of density diminishing in either direction when other strengths were used; thus, 1 to $4\frac{1}{2}$ or 1 to $5\frac{1}{2}$ were neither so dark. Other starches require a different formula.

The next series of experiments were with the view of ascertaining the effect of various acids, and other chemical substances, on the ozone powders when placed under the same bell-glass; and the result was that hydrochloric acid, nitric acid, nitrous acid, chloride of lime, phosphorus, iodine, carbonate of iron, or limestone on which an acid had been poured, each coloured the tests rapidly, whilst sulphuric acid, glacial acetic acid, carbonate of lime, carbonate of iron, and ammonia produced no effect on the powders. It was remarked that the powder tests had the advantage of being more sensitive, and that they also retained their maximum colour, not afterwards fading, as is the case with the tests of Schönbein or Moffat; and there is yet a more important advantage to be mentioned, for by their aid we are enabled to say *what colours the tests*, and whether it is really ozone. In the experiments it was found that a different colour was imparted to the powder, and that the colour penetrated deeper according to what coloured it; so that differences of effect took place by which the different materials used might be recognized, which could not be seen by the use of test-slips. Thus,—

Iodine, although coloured a *brown-black*, was merely a surface-covering, below which the powder was *colourless*.

Phosphorus.—*Bluish black* on surface only, below *almost colourless*.

Chloride of Lime.—*Deep brown* on surface only, below *slightly yellow*.

Hydrochloric Acid.—*Grey-pink* on surface only, below *orange*.

Nitric Acid.—*Dark red-brown*, extending slightly into the powder, below *colourless*.

Carbonate of Iron with Glacial Acetic Acid.—*Yellowish brown* to thickness of cardboard, below *buff*.

Limestone with Sulphuric Acid.—*Pale brown* to thickness of cardboard, below *slightly stained*.

Carbonate of Iron with Sulphuric Acid.—*Black* to depth of $\frac{1}{4}$ of an inch.

Nitrous Acid.—*Dark brown* more than the eighth of an inch deep, below *yellowish brown*.

Nitric Acid mixed with Ozone Powder (both exposed and unexposed).—*Blue-black* the sixth of an inch deep, below *reddish brown*.

The above experiments may require modification, yet they show differences so striking as to open up a new method of investigating ozone. The action of ozone on the dry-powder tests is somewhat analogous to that produced by nitric acid; yet dilute nitric acid, when ten times stronger than the French philosophers declare is the proportion present in the air, does not colour the tests. It seems probable that whatever colours the tests is always present in the air, as on no occasion has my *sensitive dry-powder test* failed to show its presence, even when test-slips have remained uncoloured for some days. Its varying intensity may be attributed to circumstances acting for or against its visibility. Thus an increase of temperature from the increased chemical action should show an increase of ozone. An increase in the velocity of air will increase the amount of ozone, because a greater number of cubic feet of ozonized air passes over the test in a given time. To a certain extent the increase of moisture will favour the development of ozone, beyond which, when the air becomes saturated, a minimum will result. Most ozone at Highfield House occurs with a S. wind, and least with a N.E. wind. The maximum amount of ozone is attained when the barometer is at its lowest readings, and the minimum when at its highest. This may be owing (and, no doubt, is in part) to the increased velocity of a S. wind over that of a N.E. wind, its increased temperature, and moisture. Supposing the amount of ozone in a cubic foot of air to be represented by 5 at a pressure of $29\frac{1}{2}$ inches, ought it not to be more than 5 when this pressure is increased, and less than 5 when diminished?—yet the contrary is shown to result in practice.

On the Connexion that exists between Admiral FitzRoy's "*Caution Telegrams*" *and the Luminosity of Phosphorus. By* Dr. Moffat.

On a Free Air Barometer and Thermometer. Devised by the Abbé Jeannon; *exhibited and explained by the* Abbé Moigno.

It consisted of a siphon of about the bore of the tube of a maximum thermometer, one branch of the siphon open to the air, the other branch furnished with two bulbs, one at top for air, the other near the bend at the bottom full of mercury, with a little glycerine oil, or other fluid not capable of acting on or absorbing the air of the upper bulb, floating on the surface of the mercury. The two bulbs are so proportioned in capacity, that the changes of the volume of the air in the upper bulb by changes of temperature are exactly compensated by the increased pressure of the mercury by the same cause, so that, as far as temperature is concerned, the surface of the mercury or glycerine between the bulbs shall remain perfectly fixed or unaffected. The branch then between the bulbs becomes a simple sympiesometer or pressure-barometer, while the open straight branch becomes a very sensitive thermometer.

On a Metallic or Holosteric Barometer. Constructed by M. Naudet; *exhibited and explained by the* Abbé Moigno.

Meteorological Observations recorded at Huggate, Yorkshire. By the Rev. Thomas Rankin.

This was the series for 1862, similar to the series which had been for several years furnished to the Association by the author.

On a new Revolving Scale for Measuring Curved Lines. By H. Schlagintweit.

This instrument consisted of a small brass wheel revolving in a short handle, the circumference, about 2 inches round, having a number of very short steel pins inserted radially, the number depending on the scale to which it was desired to measure the curve; and the side of the wheel having graduations corresponding to the pins on the circumference, the zero and other remarkable divisions being distinguished from the lesser graduations. The author entered into a minute detail of the several graduations it would be desirable to adopt to suit English, French, and German measures required for maps, courses of rivers, routes of travellers, and meteorological and other curves requiring to be measured or reduced to particular scales. He also entered into a comparison of this little roulette with "Elliott's Opisometer," and the more complicated apparatus invented by Doppler and Jacquard.

On a Proof of the Dioptric and Actinic Quality of the Atmosphere at a High Elevation. By Professor C. Piazzi Smyth, *F.R.S.*

The chief object of the astronomical experiment on the Peak of Teneriffe, in 1856, was to ascertain the degree of improvement of telescopic vision when both telescope and observer were raised some two miles vertically in the air. Distinct accounts have, therefore, already been rendered as to the majority of clouds being found far below the observer at that height, and to the air there being dry, and in so steady a state and homogeneous a condition that stars, when viewed in a powerful telescope with a high magnifying power, almost always presented clear and well-defined minute discs, surrounded with regularly formed rings,—a state of things which is the very rare exception at all observatories near the sea-level. Quite recently, however, the author has been engaged in magnifying some of the photographs which he took in Teneriffe in 1856, at various elevations, and he finds in them an effect, depending on height, which adds a remarkably independent confirmation to his conclusions from direct telescopic observations. The nature of the proof is on this wise:—At or near the sea-level a photograph could never be made to show the detail on the side of a distant hill, no matter how marked the detail might really be by rocks and cliffs illuminated by strong sunlight; even the application of a microscope brought out no other feature than one broad, faint, and nearly uniform tint. But on applying the microscope to photographs of distant hills taken at a high level in the atmosphere, an abundance of minute detail appeared, and each little separate "retama" bush could be distinguished on a hill-side $4\frac{1}{2}$ miles from the camera. Specimens of these photographs thus magnified had been introduced into the newly published volume of the 'Edinburgh Astronomical Observations,' four of them being silver-paper prints, and the fifth a press-print from a photoglyphic plate, kindly prepared and presented by Mr. Fox Talbot.

On the Comparison of the Curves afforded by Self-recording Magnetographs at Kew and Lisbon, for July 1863. *By* B. Stewart, *F.R.S.*

One point of interest in this comparison is, that a disturbance began at both places at precisely the same moment of absolute time; and a second point is, that there is great general similarity between the two curves of north and south disturbance, while in the east and west disturbance-curves the likeness is much less marked, and it scarcely appears at all in the vertical-force curves. An extremely interesting feature of the Lisbon curves of vertical force and east and west force is, that the one is nearly exactly the reverse of the other, a peak of the one corresponding in time to a hollow in the other, a hollow to a peak, and so on throughout the disturbance, which extended over twelve days. Senhor Capello, of Lisbon, remarks

that this fact may be expressed by saying that the whole disturbing force acts in *one plane*, which is evident, inasmuch as the two components alluded to are in *one line*. The comparison of these curves is believed to confirm results which have been obtained, without the aid of photography, chiefly through the sagacity of General Sabine; for it appears that at Lisbon the vertical force and east and west force are affected by only one type of disturbance, while the north and south force is under the influence of two different types; and it is believed that at Kew both types operate upon each of the three elements.

On a Mercurial Air-Pump. By J. W. Swan.

In general arrangement and appearance this instrument resembles a barometer, with a reservoir at the top and a reservoir at the bottom of the tube. Both reservoirs are of considerable capacity, but the lower one is the largest. The lower reservoir has two pipes entering it, namely, an inlet and outlet, and each has a stopcock. The upper reservoir, termed a vacuum-chamber, is surmounted by a ball-valve opening outward, and has also a tube with a stopcock communicating with the vessel to be exhausted. The vacuum-chamber, tube, and a portion of the lower reservoir are, in the normal condition of the apparatus, occupied by mercury. The remaining space within the lower reservoir is filled with water, which is separated from the mercury by a caoutchouc bag, tied on the lower end of the tube containing the mercurial column. The inlet pipe entering the lower reservoir is connected with town water-pipes or a force-pump. The working of the pump is effected by opening the outlet pipe so as to permit the mercury to vacate the vacuum-chamber and descend to the barometric level, displacing the water from the lower reservoir. Then the vacuum formed having been taken advantage of by opening the communication between the vacuum-chamber and the vessel to be exhausted, the original condition of things is restored by closing the outlet pipe of the lower reservoir, and opening the inlet, so as to supply water at a high pressure, which will force the mercury to reoccupy the vacuum-chamber, the valve at the top allowing the exit of its more or less attenuated gaseous contents. This process, being frequently repeated, will, no doubt, give a very perfect vacuum, as there is no obstruction, of the nature of a valve, between the vacuum-chamber and the vessel to be exhausted. This air-pump was said to be specially adapted for the exhaustion of small vessels. It was proposed that the instrument should be made entirely of wrought iron; among its advantages were small cost and simplicity, its efficiency not depending upon fine workmanship.

Description of the Experimental Series of Rain-Gauges erected at Calne. By G. J. Symons.

These instruments have been constructed and erected at the expense and in the grounds of Major Ward, of Castle House, Calne, with a view of finally determining the size and form of gauge which most truly indicates the amount of rain actually reaching the surface of the earth, and also deciding both the best elevation at which to place the gauge above the ground, and, if possible, the correction requisite to reduce the observations made at other elevations to what they would have been if made at the adopted standard height. The series consists of two sets of gauges: those for testing the indications of different-sized gauges are eleven in number, consisting of circular ones, 1 in., 2 in., 4 in., 5 in., 5 in. with a peculiar flange or lip, 6 in., 8 in., 12 in., and 24 in. in diameter, and square ones of 25 in. and 100 in. in area. These are all placed at the same height above the ground (1 foot), and are very near to each other. The elevation series consists of nine gauges of 8 in. diameter, placed at the following heights above the ground, viz., level, 2 in., 6 in., 1 ft., 2 ft., 3 ft., 5 ft., 10 ft., and 20 ft.; and at some distance from each other. A second gauge of 5 in. diameter is placed 20 ft. above the ground, in order to ascertain if its indications at that height bear the same ratio to an 8-inch gauge as at a less elevation. The instruments being erected in a very favourable position, free from the influence of trees or buildings, and elevated on poles, it is anticipated that the results will be more reliable and available for the before-mentioned purpose than if placed upon buildings.

On a New Marine and Mountain Barometer. By W. Symons, *F.C.S.*

The barometer shown is a modification of the portable standard siphon-barometer introduced by the author a few months since, and described in various periodicals at the time. It is an adaptation of Gay-Lussac's; but instead of having a vernier and scale to each tube of the siphon, an internal continuous metal tube is adjusted by a rack to the surface of the mercury in the short limb of the siphon, and the barometer is then read off in the usual way by a vernier and scale attached to the top of this internal tube, thus avoiding the double reading and necessary calculation of Gay-Lussac's. There is, also, a very simple but effectual method of making the barometer portable by means of a leather plug on a steel wire, attached to a small handle at the side; by shifting this handle about one-fourth of an inch, the flow of mercury is completely stopped. Marine barometers, as generally constructed, have been fractured by sudden concussions, as by firing a large gun; this arises, no doubt, from the necessity of fixing the tube firmly into the cistern. In the barometer shown this is obviated, as the tube need not be rigidly fixed, but may be supported in any point by elastic material, without deranging the accuracy of the instrument.

On a Maximum Thermometer with a New Index. By W. Symons, *F.C.S.*

Although there are two well-known and ingenious arrangements for maximum thermometers without indices, yet the constant demand for thermometers with indices shows at least a popular preference for them. There are, however, certain objections to those most generally in use. Steel not only corrodes, but its specific gravity is too great. Graphite has been much used, and if it be pure, it appears to answer every purpose; but occasionally there exist in it impurities which appear to corrode the mercury and soil the tube. The author has made a great number of experiments on the subject, and thinks he has now succeeded in making a composition, the basis of which is clay, which fully answers the purpose; for the sake of distinction, as it partakes somewhat of the character of stone, he has named it "lithite." A considerable number of these thermometers have now been distributed, and as yet there has been no failure.

On the Result of Reductions of Curves obtained from the Self-recording Electrometer at Kew. By Professor W. Thomson, *F.R.S.*

The author said, that all the photographs up to last March had been reduced to numbers, and the monthly averages taken. Each month shows a maximum in the morning, sometimes from 7 to 9 A.M., and another in the evening, from 8 to 10 P.M. There are pretty decided indications of an afternoon maximum, and another in the small hours after midnight, but the irregularities are too great to allow any conclusion to be drawn from a mere inspection of the monthly averages. He intended to calculate three terms, if not more, of the harmonic series for each month, and thus be able to judge whether the observations show any consistence in a third term (which alone would give four maxima and four minima), or a first term (which alone would give one maximum and one minimum in the twenty-four hours). There is a very decided winter maximum and summer minimum on the daily averages. That for January is more than double of that for July. This part of the subject will also require much labour to work it out. In the reductions hitherto made he had included negatives with positives, and all the sums have been "algebraic" (*i. e.* with the negative terms subtracted). Very important results with reference to meteorology will, no doubt, be obtained by examining the negative indications separately; and, again, by taking daily and monthly averages of the *fine-weather readings* alone. This part of the subject he had not been able to attack at all yet. Nor had he yet been able to go through a comparison of the amounts of effect with wind in different quarters.

CHEMISTRY.

Address by A. W. Williamson, *F.R.S., President of the Chemical Society, and Professor of Chemistry and of Practical Chemistry in University College, London.*

Before the Section enters upon the business for which it meets, viz. the consideration of papers and reports upon special branches of chemistry and the chemical arts, it may not be unacceptable to cast a brief and cursory glance at some few topics illustrative of the tendencies of chemical science during the last few years, and of its applications to some of the manufacturing arts.

One of the most remarkable features of the progress of our science is the rapid rate at which materials have been accumulating, by the labours of chemists in the so-called organic department of the science. The study of the transformation of organic bodies leads to the discovery of new acids, new bases, new alcohols, new ethers, and at a constantly increasing rate which is truly wonderful. Some of these new substances are found to possess properties which can at once be applied to practical manufacturing purposes, such as dyeing, &c., but the greater number of them remain in our laboratories, museums, and text-books, and serve to teach us new instances of the combining forces of matter. The influence of this rapid growth of materials upon our knowledge of principles, and of the laws of combination which constitute the science of chemistry, has been simultaneous with the discoveries of the materials themselves; and the material and intellectual progress of organic chemistry have gone on so regularly hand in hand, that it is impossible to say which has done most in helping the other. It is, accordingly, observed that the science has been simplified by every important addition to her materials; instead of isolated unmeaning substances, with formulæ so complex and unintelligible as to be troublesome to chemists and truly distressing to learners, we have now definite and intelligible families of bodies, of which the members are most harmoniously united together by some law of composition, and whose connexion with neighbouring families is similarly clear and satisfactory. New discoveries are constantly coming in to fill up the gaps which still disfigure our growing system.

In mineral or inorganic chemistry there is not the same scope for discovery at present, inasmuch as the elements which belong to it do not combine in those numerous proportions which occur among the chief elements of organic bodies. But yet mineral chemistry has not been standing still, for even the heavy metals, most remote in their properties from those volatile and unstable substances of organic chemistry, have been got in many instances to combine with them, and the organo-metallic bodies thus formed have not only proved most valuable and powerful agents of decomposition, but they have served as a connecting link between the two branches of chemical science. A system of classification of elements is now coming into use, in which the heavy metals arrange themselves harmoniously with the elements of organic bodies, and in accordance with the principles which were discovered by a study of organic compounds.

It is now many years since the attention of chemists was directed by a French Professor to some inconsistencies which had crept into our system of atomic weights. Gerhardt showed that the principles which were adopted in fixing the atomic weight of elementary bodies generally, required us to adopt for oxygen, carbon, and sulphur numbers twice as great as those generally in use for those elements. The logic of his arguments was unanswerable, and yet Gerhardt's conclusions gained but few adherents. It is to be observed that for some years Gerhardt represented chemical reactions by so-called synoptic formulæ, which took no account of the existence of organic radicals. These synoptic formulæ represent in the simplest terms the result of a chemical reaction; but they give no physical image of the process by which the reaction is brought about.

The introduction in this country of the watertype in connexion with polyatomic as well as monatomic radicals was found to satisfy the requirements of the synoptic formulæ. Gerhardt was the first to adopt them from us. He gave, in his admirable 'Traité de Chimie Organique,' a system of organic chemistry on that plan, and his book has been of immense service to the development of our science.

The extension of these principles to mineral chemistry had been commenced in the cases of the commonest acids and bases, but their general introduction met with difficulties, and something seemed wanting to their complete success.

I must now travel southward for a short time, and ask you to accompany me to that sunny land of glorious memories, and to its southern dependency, the Island of Sicily. It was reserved for Professor Cannizzaro, of the University of Palermo, to show us how the remainder of the knot could be untied. He argued, upon physical as well as chemical grounds, that the atomic weights of many metals ought to be doubled, as well as those of oxygen, sulphur, and carbon. His conclusion is confirmed by the constitution of those organo-metallic bodies which I mentioned just now, and it certainly does seem to supply what was still wanting for the extension of our system of classification from the non-metallic elements to the heavy metals themselves.

The elements are now arranged into two principal groups:—1st, those of which each atom combines with an uneven number of atoms of chlorine or hydrogen; 2nd, those of which each atom combines with an even number of atoms of chlorine or hydrogen. Like every classification founded upon nature, this one draws no absolute line, as some elements belong to both classes. The first group includes the monatomic elements of the chlorine family, the triatomic elements of the nitrogen family, hydrogen and the alkali metals, silver and gold, in all about eighteen elements. The usual atomic weights of these are retained. The usual atomic weights of all the other elements, biatomic, tetratomic, &c., are doubled. This second group includes the oxygen family, carbon, silicon, and the alkaline earths, the metals, zinc, iron, copper, lead, &c.

Every step in our theoretical development of chemistry has served to consolidate and extend the atomic theory, but it is interesting to observe that the retention of that theory has involved the necessity of depriving it of the absolute character which it at first possessed. Organic compounds were long ago discovered containing atoms of carbon, hydrogen, and oxygen in proportions far from simple; and the atomic theory must have been abandoned but for the discovery that the atomic or, rather, molecular weights of these compounds correspond invariably to entire numbers of the elementary atoms. We now use the term 'molecule' for those groups which hold together during a variety of transformations, but which can be resolved into simple constituents; whilst we receive the word 'atom' for those particles which we cannot break up, and which there is no reason for believing that we ever shall break up.

Amongst the most brilliant extensions of our means of observation have been the researches in spectrum analysis. The application of these beautiful methods to the investigation of minerals has already led to the discovery of three volatile metals which had previously escaped observation, whilst its extension to the investigation of the light which reaches our planet from the heavenly bodies has led to the recognition, in several of them, of elements identical, in this respect at least, with some of our elements in this earth. An eminent French chemist has recently taken occasion, in reporting the results of some researches on the new metal "thallium," to volunteer insinuations against Mr. Crookes's claim to that discovery. M. Dumas considers it corroborative of his views that Mr. Crookes did not refer the consideration of his claims, on the first opportunity, to a jury of gentlemen, formed for examining products of manufacturing industry at the National Exhibition of 1862. I have felt it my duty to allude publicly to this proceeding, because it occurred in a report of a commission of the French Academy, published by order of that distinguished body. All chemists have, however, adopted the name "thallium" which Mr. Crookes gave to the metal when he first discovered it.

Before proceeding from the scientific and intellectual progress of chemistry, I must beg leave to refer briefly to the educational effects of that progress. Little, indeed, would our conquests over nature avail us if they were only known to the systematic cultivators of science, and only used by them; and unless the popular dissemination of knowledge keeps pace with its extension, the chief fruits of that extension will be lost. It would be unjust to deny that some important steps have been taken of late years, by various governing bodies in this country, towards giving to experimental science a position in national education; but these steps are only the beginning of a reform in education, which must go much farther in order to be

effectual. In illustration of what has been done, I may mention the admission of chemistry and physics into the list of subjects of examination for various Government appointments, civil and military; but the small value which the framers of the schemes placed upon these sciences, compared to mathematics, is but too plainly shown by the small number of marks which they assign to the utmost recognized proficiency in them; so that the effect of the recognition is tantamount to saying, "We can't help acknowledging these sciences, but we want to encourage the study of them as little as possible." The medical corporations, who influence the studies of the rising generation of practitioners by their examinations, have not only recognized the necessity of a thorough knowledge of chemistry, but many of them require the knowledge to be acquired not only in the lecture-room, but partly also in the laboratory. The University of London is specially to be noticed for the beneficial influence which it has exerted in this direction in its medical examinations; but more particularly for the institution of the new degrees of Bachelor and Doctor of Science, which acknowledge, for the first time in this country, the physical and natural sciences as entitled to equal recognition with classical and mathematical studies for purposes of general education. These influences have no doubt contributed materially to the introduction of chemical instruction, and even of practical chemistry, into junior schools, which has been going on so extensively of late years. It is, however, consolatory to observe that a more powerful influence than any of these is at work, viz. the popular appreciation of its real value, gradually raising physical science to the prominent place in national education which it is destined to occupy.

If education is intended to prepare young people for a life of usefulness, in which their various faculties may be employed to the benefit of their fellow-men, and consequently to their own, there can be no doubt of the value of teaching them to observe, to recollect, to arrange the phenomena of the physical world, and to apply the knowledge and skill thus acquired to practical purposes. No phenomena that can be brought within the observation of everybody by inexpensive experiments are so simple in their nature, no reasonings more definite and tangible, or more easily controlled by special observations, than those of chemistry; and the science affords, probably, scope for a more thorough training of the various faculties of the mind than can be supplied in schools by any other means.

Among the chemical arts much has been doing, but, as usual, in a quiet, undemonstrative way. First and foremost among improvements I must mention the introduction into one manufacture after another, of those admirable furnaces invented by Mr. Siemens, and generally known as regenerative furnaces. Whether we consider them from the point of view of the economy of fuel, or whether as affording the means of attaining temperatures beyond the range of other furnaces, there can be no doubt of the immense value of this invention. Heat is the great source of power in almost all our dealings with inorganic matter, and I have not the slightest doubt that the power over heat given by these regenerative furnaces will revolutionize many a chemical art.

The manufacture of iron, and its subsequent treatment for the removal of impurities, has been of late years the subject of many experiments. Various plans have been proposed for avoiding the injurious effects of the mineral impurities of our coal, by using gas for the reduction of the iron ores. In this country, however, the manufacture of cast iron is carried on in such vast quantities that changes in the processes must meet with great resistance. The laborious and expensive process of puddling hitherto adopted for burning out the carbon from cast iron is being gradually superseded by one or other of the following:—either by treating the molten pigs with oxide of iron until the carbon is removed as carbonic oxide, or by Bessemer's process of blowing air through the molten cast iron. In either case it is desirable to add some carbon to the malleable iron in order to render it more fusible, and for this purpose the best material is the manganiferous carburet of iron, known by the name of "Spiegeleisen," of which enough is used to make a low steel of about $\frac{1}{2}$ per cent. of carbon.

One of the most interesting novelties in metallurgy is the manufacture of aluminium, now carried on for the sake chiefly of its alloy with copper, by the distinguished gentleman who holds the office of Mayor of Newcastle. The mechanical properties

of this so-called aluminium bronze give it great value, and it seems likely to find much favour for its appearance. Mr. Bell has also rendered no small service to science by collecting a large quantity of that wonderful new metal, thallium, and preparing several new salts. Among alloys, a variety of brass containing a small quantity of iron has recently attracted considerable attention. The alloy is by no means new, though hitherto known but to few persons. It combines tenacity with elasticity to a remarkable degree, and can be easily forged.

Most of the members of the Section are probably aware of the admirable series of agricultural experiments which have been proceeding for the last twenty years, under the direction of Mr. Lawes, of Rothamsted; yet many are probably unaware of the vast importance of the results already established by those experiments. Few things are perhaps more difficult than to conduct scientific experiments in any practical art like farming; to find how the resources which science discovers can be profitably turned to account, or how the defects which theory points out, in ordinary working processes, can be profitably remedied. It is almost proverbial that the greater number of persons who attempt the introduction on their farms of plans suggested by abstract science, succeed only in finding how to lose money. It does indeed require a rare combination of enthusiasm with caution, of knowledge of theory with practical experience of the conditions of ordinary working, to carry such experiments to a definite and useful issue. Such rare combinations of qualities have existed in Mr. Lawes; and when we recollect that by associating Dr. Gilbert with his labours he obtained the cooperation of an able and accomplished chemist, we have no longer reason to wonder that the results of twenty years' continuous experiment, conducted on an ample scale, with the most scrupulous care and systematic order, should have led to the establishment of results so numerous and important as to secure for Mr. Lawes the highest rank among the founders of scientific agriculture.

In speaking of the chemistry of agriculture, I cannot omit alluding to the writings of Liebig, which have rendered such important services by bringing vividly before the English agriculturists what was known of the chemistry of farming, and several ingenious and suggestive theories relating to practical agriculture. In the introduction to the last German edition of his 'Agricultural Chemistry,' Liebig refers in terms of studied disrespect to the investigations of Mr. Lawes, and while misquoting a paragraph in one of Mr. Lawes's publications, endeavours to convey the impression that that gentleman was unacquainted with the correct use of the term "mineral," and had misunderstood Liebig's mineral theory; which he is generally considered to have disproved. I mention this circumstance with pain, and have no doubt that all who value Liebig's truly important scientific labours will regret it as much as I do.

Another practical question which science has latterly brought prominently before the attention of the public is that of the utilization of the drainage of towns. It is estimated that the quantity of nourishment for plants wasted in London alone in this form is worth about a million sterling per annum; but this valuable material is contained in so large a quantity of water, that no plan has come into working for separating it out profitably for use. Some persons are of opinion that the sewage might with advantage be conveyed through pipes for use in the fields, especially on meadow land, to which it is most easily applicable. Baron Liebig has written a letter on the subject, which was forwarded by Alderman Mechi to the 'Journal of the Society of Arts,' containing a proposal to mix the liquid with superphosphate of lime before distributing it, by which he considers that the value of the constituents already contained in the liquid will be practically increased. It is, however, not likely that the opinion of a chemist will decide the authorities to adopt an experimental scheme of the kind, as it is really rather an engineering and commercial than a chemical question. The practical test of value commercially, is how much an article will fetch, and the data of this kind before us do not lead to the anticipation of a profit at all approaching to what theory suggests from the sale of this refuse. At Croydon (a town of about 18,000 inhabitants) it appears that the use of the whole sewage has only added about a thousand pounds to the rent of a farm on which it is used.

Another refuse material which has already come to possess great value is coal-

tar. Not only is our chief supply of ammonia, the food of plants, derived from that source, but those brilliant and varied colours which are now so much in use for dyeing silk also owe their origin indirectly to the same source. There is perhaps no more striking instance of the benefits which ultimately arise even to the manufacturing arts, from every complete investigation of chemical substances, than is afforded by those beautiful dyes which have sprung up today from aniline, which yesterday was a chemical novelty in the hands of a first-rate investigator.

On some Results of Experiments on Lucifer Matches and others ignited by Friction. By Professor ABEL, *F.R.S.*

Having mentioned the components of the frictional composition, or the *heads* of the principal English and Foreign matches, he went on to notice the possible causes of accident in the transport of matches. The result of experiments proved that no degree of heat to which, under all ordinary circumstances, matches were likely to be exposed in their transport or otherwise, would suffice to lead to their spontaneous ignition. It was quite within the range of possibility, however, that on board ship continuous concussion, combined with a degree of heat, might bring about accidental ignition of matches, while it might be granted that the accidental ignition of one or two boxes in securely closed cases might frequently occur almost without a possibility of fear of its spreading to other boxes. A knowledge of the causes of the accidental ignition of gunpowder and other explosives rendered it advisable that such precautionary measures as were obvious and easily observed should be attended to in the shipment of matches, with the view of reducing such occurrences to the minimum extent. Some of those steps he specified. The first was the appropriation of a place for the reception of such packages, distinct from all other merchandise. Secondly, the efficient ventilation of that part of the vessel in which matches were stowed. Thirdly, the enforcement of rules to prevent fire being brought by sailors within the vicinity of the matches. Fourthly, the carefully packing of the match-boxes into cases, so as to prevent any independent motion. And, fifthly, the bestowal of more uniform attention on the production of stout and sufficiently stable match-boxes, and on the packing of the matches into the boxes.

On the Impurities contained in Lead, and their Influence in its Technical Uses. By W. BAKER, *F.C.S.*

Having noticed the characters by which pure lead is known, the author proceeded to point out the impurities which render it hard, and what elements may exist in it without impairing the qualities which render it suitable for its various technical uses. The substances which commonly impart hardness to lead are sulphur, antimony, and arsenic. Copper, if alone, does not much affect the softness of lead. Iron also, in the absence of sulphur, is not found in sufficient quantity to produce hardness. Refining processes for impure lead are essentially oxidizing processes. When the antimony is not more than 1 to 2·070, as in Derbyshire slag-lead, the pigs are placed on the bed of the ordinary reducing furnace and melted down with free access of air. The separation of the lead from its impurities being effected by taking advantage of the difference between the melting-points of lead and the mixed sulphides, the latter are left on the bed of the furnace, whilst the purified lead in an oxidizing atmosphere runs into the pot. The writer has introduced an oxidizing agent for effecting the softening of slag-lead as it is tapped from the blast-furnace. The softened lead is treated by Pattinson's process for the concentration of silver. It is highly important for certain technical uses that lead should be practically free from copper. Less than 2 oz. per ton will produce a pink tint on white-lead corrosions, and good red lead for glass-making should not contain more than 1 oz. per ton.

On the Manufacture of Aluminium. By I. L. BELL, *Mayor of Newcastle.*

The progress of the manufacture of this—so far as the arts are concerned—new metal has scarcely been such as to require much to be added to those admirable

researches bestowed upon the process by the distinguished chemist, M. St. Claire Deville, of Paris. Upon the introduction of its manufacture at Washington, three and a half years ago, the source of the alumina was the ordinary ammonia-alum of commerce (a nearly pure sulphate of alumina and ammonia). Exposure to heat drove off the water, sulphuric acid, and ammonia, leaving the alumina behind. This was converted into the double chloride of aluminium and sodium by the process described by the French chemist, and practised in France, and the double chloride was subsequently decomposed by fusion with sodium. Faint, however, as the traces might be of impurity in the alum itself, they to a great extent, if not entirely (being of a fixed character when exposed to heat), were to be found in the alumina. From the alumina, by the action of chlorine on a heated mixture consisting of this earth, common salt, and charcoal, these impurities, or a large proportion thereof, found their way into the sublimed double chloride, and, once there, it is unnecessary to say that, under the influence of the sodium in the process of reduction, any silica, iron, or phosphorus found their way into the aluminium sought to be obtained. Now it happens that the presence of foreign matters, in a degree so small as almost to be infinitesimal, interferes so largely with the colour as well as with the malleability of the aluminium, that the use of any substance containing them is of a fatal character. Nor is this all, for the nature of that compound which hitherto has constituted the most important application of this metal—aluminium-bronze—is so completely changed by using aluminium containing the impurities referred to, that it ceases to possess any of those properties which render it valuable. As an example of the amount of interference exercised by very minute quantities of impurity, it is perhaps worthy of notice that very few varieties of copper have been found susceptible of being employed for the manufacture of aluminium-bronze; and hitherto the author has not, nor have they in France, been able to establish in what the difference consists between copper fit for the production of aluminium-bronze and that which is utterly unsuitable for the purpose. These considerations have led us, both here and in France, to adopt the use of another raw material for the production of aluminium, which either does not contain the impurities referred to as so prejudicial, or contains them in such a form as to admit of their easy separation. This material is Bauxite, so called from the name of the locality where it is found in France. It contains

Silica	2·8
Titanium	3·1
Sesquioxide of iron	25·5
Alumina	57·4
Carbonate of lime	0·4
Water	10·8
	100·0

The bauxite is ground and mixed with the ordinary soda-ash of commerce, and then heated in a furnace. The soda combines with the alumina, and the aluminate of soda so formed is separated from the insoluble portions, viz. peroxide of iron, silico-aluminate of soda, &c., by lixiviation. Muriatic acid or carbonic acid is then added to the solution, which throws down pure alumina. The remainder of the process is precisely that which is described by M. St. Claire Deville. The alumina is mixed with common salt and charcoal, made into balls the size of an orange, and dried. These balls are placed in vertical earthen retorts, kept at a red heat, and through the heated contents chlorine gas is passed. The elements of the earth, under the joint influence of carbon and chlorine at that temperature, are separated—the carbon taking the oxygen, and the chlorine the aluminium. This latter substance, accompanied by chloride of sodium, sublimes over, and is collected, as a double chloride of aluminium and sodium. In small iron retorts, kept at as high a temperature as iron can bear, a mixture of soda (carbonate of soda) and carbonaceous matter, with a little ground chalk, is placed. The metallic base of the alkali distils over and is collected in coal oil. A portion of the double chloride and sodium, along with fluxes, is exposed to a full red heat in a reverberatory furnace. The

sodium seizes the chlorine combined with the aluminium, and thus liberates the latter metal, which falls to the bottom of the fused mass.

Aluminium is used in sufficient quantity to keep the only work in England—viz. that at Washington—pretty actively employed. As a substance for works of art, when whitened by means of hydrofluoric and phosphoric acid, it appears well adapted, as it runs into the most complicated patterns, and has the advantage of preserving its colour, from the absence of all tendency to unite with sulphur, or to become affected by sulphuretted hydrogen, as happens with silver.

A large amount of the increased activity in the manufacture referred to is due to the exceeding beauty of the compound with copper, already spoken of, which is so like gold as scarcely to be distinguishable from that metal, while it possesses the additional valuable property of being nearly as hard as iron.

This alloy, or aluminium-bronze as it is termed, is a discovery of Dr. John Percy, F.R.S., and appears to be a true chemical compound. Copper is melted in a plumbago crucible, and after being removed from the furnace, the solid aluminium is added. The union of the two metals is attended with such an increase of temperature that the whole becomes white hot; and unless the crucible containing the mixture is of refractory material, a vessel which has resisted a heat sufficient to effect the fusion of copper melts when the aluminium is added.

Mr. Gordon was the first, it is believed, who detected and determined the amount of tension wire of aluminium-bronze was capable of resisting, which he found to be between that of the best iron and the best steel wire. Colonel Strange, of the Royal Astronomical Society, investigated its properties, which were given in a very able paper in the 'Transactions' of that body. Its malleability, ductility, and capability of being finely divided and engraved upon, along with its great strength, induced the Colonel to recommend its adoption in the theodolite used in the Trigonometrical Survey of India.

At the Elswick Ordnance Works, Captain Noble, R.A., confirmed previous experiments on the capability of aluminium-bronze to resist longitudinal and transverse fracture, and in addition to this he ascertained that its position to withstand compression stood halfway between that of the finest steel and the best iron.

The bronze containing ten parts of aluminium and ninety of copper affords an alloy endowed with the greatest strength, malleability, and ductility. The colour of the copper is affected by a very trifling addition of the other constituent, and the alloy gradually improves in these valuable qualities just mentioned until the proportions given above are reached. After this, *i. e.* when more than 10 per cent. of aluminium enters into the composition of the bronze, the alloy gradually becomes weaker and less malleable, and at length is so brittle that it is easily pounded in a mortar.

On Thallium. By I. Lowthian Bell.

The persevering labours of Mr. W. Crookes in connexion with this newly discovered metal had shown it to exist, in notable quantities, in a sublimate found in flues leading from the kilns, in which certain kinds of pyrites are treated for obtaining sulphuric acid. The author caused the substance found in the apparatus connected with the leaden chambers at Washington to be examined, and ascertaining that thallium really was present, he requested M. Henri Brivet, the chief of the laboratories at Washington, to continue the researches and prepare a sufficient quantity both of the metal and of its salts for exhibition at the present Meeting of the British Association. Some of the results (perhaps all) may have been observed by other chemists, but in a subject of such recent discovery as thallium, confirmation of the labours of others is not without its value. This paper does not profess to be more than a record of the various substances obtained by M. Brivet, upon whom the entire labour devolved of preparing, and to whom in consequence the whole merit is due for the information now submitted to this Meeting.

The sublimate varies considerably in appearance, sometimes of a whitish yellow and at others of a chocolate colour, and these two not unfrequently alternate in distinct layers. The reddish colour in the latter is due to oxide of iron and oxide of manganese. In both these thallium is to be found in the state of a sulphate, to an extent indicated by the following analysis:—

Earthy matter	6·75
PbO	21·36
Alumina	1·30
FeO	18·90
MnO	1·65
CaO	4·05
MgO	0·55
SO^3	28·45
ThO	7·55
Az H^3	1·80
Se As Zn, &c. not estimated	7·64
	100·00

Wishing to free the solution, obtained by treating this mass with water, from iron, lime was added. This plan was not the one ultimately adopted, but during its application a considerable quantity of ammoniacal vapours made their appearance, and these were afterwards found to be due to the presence of sulphate of ammonia in the sublimate itself, possibly due to the fact that some pyrites from the collieries is used, and adhering coaly matter may have given rise to the generation of the alkali.

A concentrated hot solution of all the salts obtained from 4 cwt. of the flue sublimate gave a salt which fell in granular crystals; others of an octahedral shape fell subsequently from the same solution, and were found on analysis to consist of

HO	36·50
SO^3	26·40
$Al^2 O^3$	9·50
FeO	1·80
ThO	20·45
Az H^3 (not weighed)	5·35
	100·00

As a source of thallium, the whole solution was treated in two ways.

First, the solution not sufficiently strong to give any crystals was filtered, and to it a piece of sheet zinc was added; this, by its conversion into sulphate of zinc, gave the thallium as a metallic precipitate, but contaminated with the impurity of the zinc. This metallic precipitate was washed with water and again dissolved in sulphuric acid, and then precipitated by means of hydrochloric acid. The chloride of thallium being feebly soluble in water, the washings of the chloride were preserved and used for washing out, in subsequent operations, the sulphate of thallium from flue-dust. The pure chloride thus obtained was either reconverted into sulphate and then precipitated by an electric current, or the chloride was fused, placed in a dish, after cooling in water, with a piece of zinc, which reduced the metallic thallium as before. The metal itself preserves the exact physical structure of the cake of the chloride of thallium. The metal so obtained by either of these modes was melted, and both were of the same degree of purity. They gave the following results on analysis:—

Thallium	98·66
Si	·36
Fe	·34
Loss	·64
	100·00

The second and more economical mode of treatment consisted in taking the solution obtained from the flue sublimate and adding chloride of sodium until all precipitation ceased. The acid solution remaining after the chloride has been precipitated, contains more thallium than an ordinary neutral solution, and in consequence was preserved. The solution was concentrated, and crystals of sulphate of iron and sulphate of ammonia separated. The mother-liquor, on being treated with chromate of potass, gave chromate of thallium, which was exhibited as one of the

salts of this metal. The chloride of thallium so obtained was treated in the manner already described for procuring the metal. Before dismissing the subject of the flue dust, it may be well to say that it consisted principally of sulphate of lead, caused by the presence of sulphide of lead in the pyrites, earthy matter, &c., with a small quantity of thallium, as was manifest in reducing the sulphate of lead, when the metallic lead was found to contain thallium, as shown by the subjoined analysis.

Thallium	7·69
Pb	91·53
Loss	·78
	100·00

In all, about eight pounds of thallium have been procured in the way described. Six pounds of metallic thallium were exhibited; one pound was presented to Mr. Crookes and to some chemical friends in Paris, and the remainder has been employed in forming the salts exhibited, viz.:—

Sulphate.—Sulphuric acid dissolves the metal with great readiness, giving off hydrogen, the solution on concentration affording crystals.

Nitrate.—Nitric acid also dissolves the metal with ease, giving off nitrous vapours, the solution affording crystals in the ordinary way.

Carbonate.—A solution of thallium not being, like that of lead, &c., precipitated by an alkaline carbonate, the following process was followed. The spongy metallic thallium precipitated by zinc from the chloride was moistened and heated gently and exposed to the air. The greater portion of the thallium oxidized, which oxide was then dissolved in water, and a stream of carbonic acid was passed through the solution. This converted the oxide into carbonate, and from the solution of carbonate of thallium so obtained, crystals of this salt were procured by concentration in the usual way. Exposure to the atmosphere produced similar results, *i. e.* carbonic acid was absorbed, just in the same way as happens when solutions of potass, soda, lime, &c. are similarly treated.

Chromate, obtained in the way already described, by adding chromate of potass to a solution of any soluble salt of thallium.

Bichromate, got by using bichromate instead of the chromate. If the bichromate is precipitated from an acid solution and heated to ebullition, and the solution allowed to cool, the crystals fall in brilliant scales, as may be seen on examining the specimens.

Chloride of Thallium, obtained in the way already mentioned, as a precipitate. This precipitate, dissolved in a boiling solution of muriate of ammonia, gave crystals on cooling, the chloride being more soluble in muriate of ammonia than in water. A specimen of melted chloride answering to what may be denominated horn thallium was also prepared.

Sesquichloride of Thallium.—On treating the chloride of thallium with boiling nitric acid, all the chloride dissolves, and the solution, on cooling, deposits brilliant yellow scales of a sesquichloride. This sesquichloride was exhibited, after having been melted.

Iodide of Thallium, obtained by precipitating a solution of sulphate of thallium by iodide of potassium, giving a very insoluble yellow precipitate, which, on being heated when dry, changes to orange, regaining the primitive colour on cooling.

Sulphate of Thallium and of Alumina.—The addition of the sulphate of alumina to a solution of sulphate of thallium gave this double salt resembling in form those of alum; and, indeed, this substance may be considered as a thallium-alum. The existence of a double salt of this description is interesting, inasmuch as it forms a link with the alkalies.

Sulphate of Thallium and of Soda.—On adding caustic soda to the solution of sulphate of thallium, in treating the flue sublimate with hot water, iron is first thrown down and ammonia given off. The hot strong solution on cooling gives crystals of sulphate of soda, containing sulphate of thallium; but whether mechanically or otherwise, want of time has not permitted the determination. A specimen of these crystals was shown.

Sulphocyanide of Thallium.—When a solution of sulphate of thallium has added

to it another of sulphocyanide of potassium, a sulphocyanide of the former metal, in long white crystals, falls.

This is necessarily a very imperfect paper in an exclusively scientific point of view. Both the writer and his friend M. Brivet had been too much occupied in other affairs connected with the Meeting to devote that time to its preparation the interest of the subject entitles it to. The results were in consequence confined to procuring the salts, and any further examination of them must be reserved for the future. The results already obtained, indeed, were somewhat abridged by the indisposition of M. Brivet, occasioned by frequent contact with the metal, or rather in breathing its fumes; at all events, his symptoms, those of languor and headache, corresponded with those already described by another operator.

On Minerals and Salts found in Coal-pits. *By* R. Calvert Clapham *and* John Daglish, *F.G.S.*

In conducting the extensive coal-mining operations in the counties of Northumberland and Durham, many interesting minerals and salts are met with, which are little noticed by mine-adventurers, as they do not bear directly on the material sought for. Some of these substances have been formed simultaneously with the coal, or at least at periods far removed from the present time, whilst others are of recent formation. Having had favourable opportunities of obtaining and examining specimens, the writers proposed briefly to describe the results, and, in doing so, divided the paper into the following heads:—

1. Coal, and,
2. The adjoining rocks which were formed nearly simultaneously with it.
3. The minerals and other foreign substances found in coal.
4. The salts found in coal, and formed by decomposition and recombination.

1. *Coal.*—One of the most striking peculiarities of the northern coal-field is the variety in the economic quality of the various beds of coal—the same seam being in different parts a household, a gas, a coking, and a steam coal; and this occurs without any great alteration in its chemical constituents, and probably arises from a different combination of elements or in mechanical structure.

The household coal has a hard fracture, and in burning leaves little ash, and that of a red colour. The essential economic character of gas coal is the yielding of a large quantity of gas on distillation, together with freedom from sulphur and other impurities. The requisite of coking coal is that, on roasting in close ovens, it should yield a hard and compact coke, free from sulphur and from slaty particle, which, on burning, would leave clinkers and destroy the fire-bars. The steam coal is a very hard, free burning, white ash, non-caking coal.

2. *The Rocks adjoining the Coal* consist chiefly of bituminous and non-bituminous shales, sandstone, ironstone, and limestone; and although they possess numerous distinctive features of very great interest, a lengthened description would be foreign to the purpose of this paper, and is the less required, as their general properties have been frequently described and are well understood. Specimens were however, exhibited, and a brief analysis of each annexed, for the object of showing more clearly the part they play in the formation of the salts, &c., hereafter to be described. The following are the specimens selected:—

1. Specimen of non-bituminous shale, from Messrs Cowen's Pit, at Blaydon.
2. Specimen of blue shale, from Newsham Colliery, near Blyth.
3. Specimen of bituminous shale, from the roof of the Low Main or "West Hartley" seam, at the same mine.
4. Specimen of mussel-band ironstone, from a bed lying five feet above the Low Main seam, in the Bedlington Pit, and clay-ironstone, from Hetton Colliery.
5. Specimens of sandstones used for building up-cast shafts.

The specimens of sandstone were from various well-known quarries in the coal-measures.

The chief characteristic of these sandstones seems to be the quantity of iron, lime, or magnesia they contain, which is the cause of their decomposition when exposed to the action of disintegrating agents, and has led to serious loss through

the decomposition of the stones with which the sides of many of the up-cast shafts in this district are lined, by the sulphurous vapours from the ventilating-furnaces and engine-fire. This is remedied by the adoption of fire-bricks in the place of sandstone, the latter not being liable to decomposition under the circumstances to which they are exposed.

With the object of showing the action of these gases, the writers have examined various specimens of metal tubbing taken from the shafts of Hetton and other collieries, after having been some years in use, and append the analyses:—

	No. 1.	No. 2.	No. 3.	No. 4.
Iron	72·00	3·00	59·20	—
Sulphur	3·00	1·42	3·28	2·05
Carbon	3·85	55·35	25·72	—
Silica	0·65	34·15	—	—
Water	16·00	6·20	14·72	—
	95·50	100·12	100·00	

The following are some analyses of sandstones:—

Recent Analyses of Sandstones.

	PENSHER.			COX GREEN.			Crag-leith sand-stone.	Mica-ceous sand-stone.
	Brown rock.	White rock.	Grey rock.	Top stone.	Middle stone.	Bottom stone.		
Silica	78·50	88·00	84·50	78·83	81·60	83·30	86·33	76·25
Alumina	16·00	10·00	5·50	12·16	9·60	9·16	9·83	8·12
Oxide of iron	5·00	1·16	5·30	6·00	6·60	6·00	2·60	9·53
Carbonate of lime	0·21	0·20	0·30	1·40	1·20	0·34	1·60	1·11
Carbonate of magnesia	0·30	0·20	trace	0·30	0·40	0·30	trace	0·32
Salts of soda and potash	traces	trace	trace	trace	trace	trace	trace	3·40
	100·01	99·56	95·60	98·69	99·40	99·10	100·36	98·73

3. *Minerals and other Foreign Substances found in Coal.*—Many of these are omitted in printed analyses, as they exist in separate masses and are not uniformly intermixed throughout the coal. They chiefly consist of—

(1.) Carbonate of iron.
(2.) Sulphuret of lead.
(3.) Sulphuret of copper.
(4.) Sulphuret of baryta.
(5.) Carbonate of lime.
(6.) Arsenic.
(7.) Hatchetine.
(8.) Sulphuret of iron.
(9.) Sulphuret of nickel.

A few of these we shall describe.

(A.) Specimen from the centre of the Hutton coal-seam, at Seaton Colliery, near Seaham, at a depth of 1500 feet; it consists of sulphurets of iron and copper.

The analysis of a large specimen is as under:—

Copper	33·20
Iron	28·20
Sulphur	37·00
Carbon, &c.	1·60
	100·00

(B.) Specimen of Sulphuret of Lead from Seaton Colliery.

The following in an analysis of a specimen:—

Lead	52·48
Sulphur	11·40
Iron	2·10
Coal, &c.	34·02
	100·00

(C.) Iron pyrites, locally termed "brasses," is found in nearly all coal, and

sometimes to a very considerable extent. A large quantity is separated from the coal on its arrival at the surface of the mine; but a great part of it is thrown to waste, and forms the "fire-heaps" attached to nearly every colliery, and is frequently the cause of considerable damage to vegetation when they take fire.

Probably as much as 20,000 tons per annum are saved, and used in the manufacture of sulphate of iron and sulphuric acid.

The following is an analysis of cleaned coal-pyrites from Walker Colliery:—

Sulphur	40·50
Iron	36·35
Coal	17·90
Silica	1·55
Carbonate of lime	4·00
	100·30

Still more recently a further quantity—(D.) Specimens of Hatchetine—was found in the South Hetton Pit, some of which the writers hoped to have been able to lay before the members of the Association; but unfortunately the pit-boys found it out, and used it for greasing the axles of their trams, thus making it deserve the name of "mineral grease," which it sometimes receives.

(E.) Specimen of coprolite found in the bituminous shale lying immediately over the Low Main seam at Newsham Colliery, near Blyth: from the numerous fish-remains found in this bed, it has received the name of "Fish-bed." This specimen contains 30 per cent. of phosphate of lime.

(F.) Specimen of sulphate of baryta, found in Felling Colliery, near Newcastle, by Mr. G. B. Foster, in quite a large mass. The writers are not aware of sulphate of baryta having previously been noticed in connexion with coal, except by Dr. Richardson, of Newcastle, who observed it in the waters of Walker Colliery in 1847.

(C.) Specimen of carbonate of lime, generally found in layers, occasionally of several inches thick, and frequently presenting the appearance of fine marble.

(H.) Specimen of carbonate of iron, also found in layers, and frequently mixed with lime, also in large masses.

(I.) Arsenic is not found isolated, but in some coal "brasses" it exists to the extent of 0·1 to 0·3 per cent.

(J.) Specimen containing fine crystals of sulphuret of nickel, imbedded in carbonate of lime, from South Wales.

4. *The Salts formed by Decomposition and Recombination.*—Through the rocks described in the first part of this memoir water is constantly percolating, and this, becoming charged with various salts in its passage through the upper strata, induces decomposition of many of the previously mentioned substances, thus forming new combinations. These are in some cases found in solutions of various densities, sometimes in crystallized masses of great purity, and at other times in layers deposited from solution or by evaporation. We shall give a few illustrations:—

(K.) A specimen from Hetton Colliery, which consists of crystallized sulphate of iron (copperas). This is sometimes found in considerable quantities.

(M.) Specimen of sulphate of alumina, containing 29·6 per cent. sulphate of alumina, soluble in water. This substance is found in considerable quantities in Hetton Colliery.

(N.) Specimen of sulphates of iron and alumina (iron-alum, very pure). This is found in fine crystallized masses.

(O.) Specimen of sulphate of lime, from Walker Colliery, from a large mass of snow-like crystals.

(P.) Specimen of needle-shaped crystals of Epsom salts. This substance is found in large quantities in Hetton Colliery, and is quite pure.

(Q.) Specimen of nearly pure common salt, with a trace of sulphate of lime.

(R.) Specimen of chloride of potassium, mixed with common salt.

In presenting the above imperfect results to the Members, the writers are well aware that they have not exhausted the subject; but, amidst the more important duties of the last few months, it has been found difficult to find time sufficient to complete the paper that they had sketched out for themselves.

On Disinfectants. *By* H. B. Condy, *F.C.S.*

It was remarked by the author, that the idea of artificial disinfection by chemical means was not opposed to the operations of nature, since the action of the air in overcoming the foulness which is inseparable from the congregating together of men in dwellings is explainable only by the laws of chemistry. The atmosphere is an admixture of chemical substances, whose influence on organized being, whether in its constructive or destructive effects, is of a truly chemical nature. In studying, consequently, the best means of seconding nature in her efforts for disposing of the waste products of organic life, we had only to copy her admirable processes, in order to arrive at the most perfect results. The researches of recent times on the composition and economy of the atmosphere pointed clearly to oxygen, and especially to active oxygen, as the chief means by which natural disinfection is accomplished. There are two classes of circumstances in which the auxiliary aid of disinfectants is very frequently required to overcome unwholesome influences, viz., 1st, against the deleterious emanations which generally proceed from the bodies of men, especially when labouring under disease, and more particularly when such disease is of a contagious nature; 2nd, against the taint of organic decomposition. In both these cases the chemical objects to be kept in view were substantially the same. The infective material in either case is supposed to be an organic compound, declining by successive transformations from a highly complex form towards that state of ultimate repose which belongs to complete oxidation. Its dangerous qualities are dependent on its condition while passing through those steps of transition during which it acts after the manner of a ferment. Disinfectants are of two classes:—1st, those which, by fixing the organic matter in a form unfavourable to oxidation, thus reduce to the utmost its tendency to undergo chemical change, and which are more properly designated *antiseptics*; 2nd, those which more or less rapidly break up the organic matter by producing its oxidation and conversion into imputrefiable products, and which alone are properly designated *true disinfectants.* The advantages possessed by the preparations indicated by the author were thus summed up:—they had no smell whatever of their own, gave off no odorous gas during their operation, and when diluted for use were devoid of perceptible action, except on offensive matter; they were thoroughly efficient and permanent in their effects, disinfecting as well as deodorizing; perfectly safe to us, because not poisonous; not mistakeable for other substances, on account of their characteristic colours; capable of being regulated as to quantities required by the depth of colour of their solutions; and applicable in a great number of cases for which no other disinfecting agents can be employed.

On Fire-clay Goods.* *By* Joseph Cowen, Jun.

The author stated that fire-clay, which is obtained in large quantities in the two counties of Durham and Northumberland, usually lies beneath the coal-measures, in layers varying in thickness from 12 inches to 5 or 6 feet. The refractory character of any sample of fire-clay is determined by the proportions in which silica and alumina are present, and by the absence of lime, iron, and other easily fluxible substances. The best descriptions of fire-clay—those which, when manu-

	1.	2.	3.	4.	5.	6.	7.
Silica	51·10	47·55	48·55	51·11	71·28	83·29	69·25
Alumina	31·35	29·50	30·25	30·40	17·75	8·10	17·90
Oxide of iron	4·63	9·13	4·06	4·91	2·43	1·88	2·97
Lime	1·46	1·34	1·66	1·76			1·30
Magnesia	1·54	0·71	1·91	trace	2·30	2·99	
Water and organic matter	10·47	12·01	10·67	12·29	6·94	3·64	7·58

* This paper was drawn up by the author at the request of the Local Committee.

factured, are capable of resisting the greatest heat—always contain a large portion of silica. The preceding Table contains a series of analyses of samples of fire-clay taken from seven seams, all worked in the mines belonging to one fire-brick manufactory, situated a few miles west of Newcastle.

The remaining part of the paper treated at length of the various applications which have been found, especially in late years, for articles made from this substance.

On the Extraction of Thallium on a large scale from the Flue-dust of Pyrites-burners. By W. Crookes, *F.R.S.*

Having for some months past been occupied, in conjunction with Messrs. Hopkin and Williams, in the extraction of thallium from an amount of material far greater than has ever been treated before, the author proposed to bring before the Meeting an account of the methods ultimately adopted.

The author has received some hundreds of specimens of deposit, flue-dust and minerals, every one of which was first of all carefully tested for the metal by means of the spectroscope. The practical employment of spectrum analysis is, he regretted to say, of but very limited use, and has caused him many disappointments before he determined to abandon it, except for confirmation in subsequent experiments. The spectrum by itself gives no indication of quantity; the green line produced by a residue containing but one part of thallium in a thousand is as vivid and distinct as the line given by the pure metal; and therefore, before he could decide whether a deposit contained sufficient thallium to repay for its extraction, it was necessary to make an estimation in the moist way, by exhausting a weighed quantity of the dust with water, and adding hydrochloric acid to the solution. Associated with thallium in these deposits is, unfortunately, a variety of other metals, among which he found mercury, copper, arsenic, antimony, iron, zinc, cadmium, lime, and selenium, together with ammonia, sulphuric, hydrochloric, and nitric acids.

Soon after the publication of his lecture delivered at the Royal Institution, March 27, 1863, Dr. Alfred S. Taylor sent me a powder, which is, beyond doubt, a portion of the residue in which Berzelius found selenium. He examined the specimen with the most scrupulous care in the spectroscope, but have been unable to see the faintest trace of the green line. Had thallium been present, it would scarcely have escaped the keen observation of Berzelius.

The flue-dust upon which we have as yet operated amounts to about five tons, the whole of which has been treated by the method he is about to describe. The difficulties of manipulating such an amount have been very serious. The process at present adopted at Messrs. Hopkin and Williams's laboratory is as follows:—The thalliferous dust is first treated in wooden tubs with an equal weight of boiling water, and is well stirred. During this operation a considerable quantity of nitrous acid is evolved; after which the mixture is allowed to rest for twenty-four hours for the undissolved residue to deposit. The liquid is then siphoned off, the residue is washed, and afterwards treated with a fresh quantity of boiling water. The collected liquors which have been siphoned off from the deposit are allowed to cool, precipitated by the addition of a considerable excess of strong hydrochloric acid, and the precipitate, consisting of very impure chloride of thallium, is allowed to subside. The chloride obtained in this way is then well washed on a calico filter, and afterwards squeezed dry. He mentioned that from three tons of the dust he obtained 68 pounds of this rough chloride.

The next step consists in treating the crude chloride in a platinum dish with an equal weight of strong sulphuric acid, and afterwards heating the mixture to expel the whole of the hydrochloric acid. To make sure of this, the heat must be continued until the greater part of the excess of sulphuric acid is volatilized. After this the mass of sulphate of thallium is dissolved in about twenty times its weight of water, and the solution filtered. On the addition of hydrochloric acid to this solution, nearly pure chloride of thallium is thrown down; this is collected on a calico filter, well washed, and then squeezed dry.

It is now necessary to again convert the chloride into sulphate. For this purpose we add the dry chloride gradually to hot sulphuric acid, using four parts by

weight of strong acid to six parts of the chloride. The mixture so obtained is heated strongly until all the hydrochloric acid is expelled and the residue assumes the form of a dense liquid. This, being set aside, solidifies on cooling to a white crystalline mass. When this is dissolved in water an immense amount of heat is evolved, and great care must be taken to avoid breakage of the vessels. The best way of dissolving it is to add it slowly to ten times its weight of hot water. A solution is thus obtained, which must be filtered; and on being concentrated and set aside to cool, crystals of sulphate of thallium will be obtained, which may be rendered quite pure by recrystallization,—a little hydrosulphuric acid being previously added, if necessary, to separate arsenic, mercury, &c.

The final step in the process is the reduction of the metal from this sulphate. Plates of pure zinc (which must leave no residue whatever when dissolved in sulphuric acid) are arranged vertically round the sides of a deep porcelain dish holding a gallon. About seven pounds of crystallized sulphate of thallium are then placed in the dish, and water poured over to cover the salt. Heat is applied, and in the course of a few hours the whole of the thallium will be reduced to the state of a metallic sponge, which readily separates from the plates of zinc on slight agitation. The liquid is poured off, the zincs removed, and the spongy thallium washed two or three times. It is then strongly compressed between the fingers, and preserved under water until it is ready for fusion. The fusion of the metal is readily effected. An iron crucible is placed over a gas-burner, and a tube is arranged so that a constant stream of coal-gas may flow into the upper part of the crucible. Lumps of the compressed sponge are then introduced, one after the other as they melt, until the crucible is full of metal. It is then stirred up with an iron rod, and the thallium may either be poured into water and obtained in a granulated form, or cast into an ingot. Thirty or forty fusions have been performed in the same crucible without the iron being acted upon in the least by the melted thallium. The products of these fusions were ultimately melted together and cast in an iron mould. The bar of metallic thallium exhibited before the Section weighed a quarter of a hundredweight.

Thallium contracts strongly on cooling. The coating of tarnish which it acquires while hot is instantly removed by water, which renders the surface perfectly bright. The liquid metal in the crucible, when protected by the stream of coal-gas, can scarcely be distinguished from mercury. Thallium is not absolutely identical in colour with any other metal, but approaches nearest to cadmium and tin. It has perfect metallic lustre. Its specific gravity is 11·9. It is very malleable, but not very ductile. It can only be drawn into wire with great difficulty; but by the operation technically known as squirting, thallium wire may be formed most readily. Thallium is very soft, being only exceeded in this property by the alkali metals. A point of lead will scratch thallium with the greatest readiness. Thallium possesses the property, in common with soft metals, of welding by pressure in the cold. Rubbed on paper, it gives a dark streak, having a yellow reflection, which in a short time nearly fades out, but may be restored with an alkaline sulphide. Thallium is strongly diamagnetic, being in this respect nearly, if not quite, equal to bismuth. It melts at 550° F., and distils at a white heat, evolving brown vapours into the air at a temperature little above its melting-point. When a minute fragment of thallium, or of any of its salts, is introduced into the flame of a spirit-lamp, it colours it of a most intense green, which, when examined by means of a spectrum apparatus, appears to be absolutely monochromatic, communicating one single green line to the spectrum. This property of the metal is now too well known to require further remarks; from it the name Thallium was chosen.

The atomic weight of thallium is 203. This result, however, is not deduced from sufficiently accurate analyses to render it entirely trustworthy, and the author is now engaged in determining the equivalent in a more accurate manner.

On Photelectric Engraving, and Observations upon sundry Processes of Photographic Engraving. By DUNCAN C. DALLAS.

On the Slacking of Quicklime. By JOHN DAVY, *M.D., F.R.S., &c.*

The object of the author in this communication was twofold:—first, the giving an account of certain experiments, the results of which seemed to show that lime is capable of forming with water a subhydrate, attended with the evolution of little heat; next, the suggesting the use of lime in collieries as a substitute for gunpowder in blasting, founded on the fact of the high temperature, attended with the production of steam, occasioned by the quenching quicklime,—that is, its conversion into a hydrate,—yet not sufficiently high to inflame any inflammable gas. He concluded with expressing the hope that a trial of the suggestion would be made in a colliery, being so easy of execution and attended with no danger—the great objection to the use of gunpowder. His own trials, he stated, made with borings into hard sandstone, had not succeeded, which is not surprising considering the resistance offered—so much greater than from coal—and the small quantity of lime employed.

On a new Gas-Furnace for melting Gold, Silver, Copper, Cast Iron, Glass, &c., by means of Coal-gas, without the aid of a bellows or tall chimney. By G. GORE.

This furnace consists of a stout cylinder of fire-clay, about 10 inches high and 6 or 8 inches wide, enclosed in a sheet-iron casing, to the lower and back part of which is affixed a short chimney: the casing is supported by three iron legs about 15 or 18 inches high. Inside the clay cylinder is placed a shorter and thinner clay cylinder or cupola, having three clay pegs projecting from its inner side near the top, for supporting the crucible. Both the cylinders are open at their ends, and rest upon the bottom of the iron casing. The outer clay cylinder is covered at the top by a thick circular plate of fire-clay, with a hole in its centre for inserting or removing the crucible, &c.; and this hole is closed by a plug of fire-clay. The iron casing has a large hole in the middle of its bottom part under the cupola, beneath which is fixed a peculiar corrugated gas-burner; so that the flame passes up inside the cupola, surrounding the crucible, then out at the top of the cupola, and down the outside between it and the outer cylinder, to a hole entering the chimney.

The smallest-sized furnace will melt half a pound of copper, or six ounces of cast iron. One ounce of copper has been melted in it in $2\frac{1}{4}$ minutes, one ounce of cast iron in 3 minutes, five ounces of copper in $4\frac{1}{4}$ minutes, and three ounces of cast iron in 5 minutes. The second-sized furnace will melt fifty ounces of copper, or forty ounces of cast iron; it has melted sixteen ounces of copper in 8 minutes.

The furnace is portable, requiring no brickwork erections or fixed chimney; it may be placed anywhere, and used in any situation where gas is available; it is safe in action, free from dust, and produces no smoke. A further great advantage is "the perfect accessibility which it permits to the melted metal, and the protection of the fused metal from oxidation by means of *the layer of flame* which during the action of the furnace plays over the mouth of the open crucible and excludes the atmospheric air. Thus the advantages of a covered crucible are gained, whilst the contents of the crucible are perfectly accessible to examination or manipulation." This also enables oxidable metals and alloys to be melted in an open crucible without the addition of a flux or reducing agent.

The furnaces are suitable for jewellers, dentists, analytical chemists, and all persons requiring small crucibles quickly heated to high temperatures. They may be obtained of E. W. Ball, 11 Broad Street, Islington, Birmingham.

On the Commercial Advantages of a new Carbonate of Soda. By M. L. KESSLER.

He refers to the 'Comptes Rendus' of the French Academy for January 12, 1863, for his description of the facility of obtaining, with simple precautions, beautiful crystals of this salt containing one equivalent of water. From their different crystalline form they cannot be confounded with ordinary crystals of soda. They are right prisms with square bases, sometimes terminated by a right face, but oftener by a prismatic or pyramidal summit.

The salt presents many features by which its purity can be ascertained.

1. Its striking peculiarity of form, its complete dryness, and greater specific gravity than crystals of soda.

2. It cannot be adulterated with the cheaper salts, sulphate and ordinary carbonate of soda, which contain much water, and fall into powder.

3. It is the only ordinary salt that can be heated red hot on a piece of charcoal without change of crystalline form. It merely becomes opake, while sulphate and carbonate of soda undergo watery fusion, common salt decrepitates, and nitrate of soda deflagrates. The least-instructed purchasers cannot be deceived as to its purity.

The surface with difficulty effloresces even in an atmosphere so dry as to turn in the same time a large crystal of soda into powder. As it contains only 17 per cent. of water, and 83 per cent. of carbonate of soda, the cost of distant carriage is nearly the same as that of ordinary soda-ash of 85 per cent.

The preparation is more economical than that of the two ordinary forms of soda, being produced by the "multiple" employment of heat; and it can be packed from the evaporating-pan without draining more than a moment. M. Kessler considers that all these properties point it out both for the public and the manufacturer as the most rational commercial form of soda.

On Glass-engraving by Hydrofluoric Acid. By M. L. Kessler.

The two principal glass-works in France, St. Louis and Baccarat, have used for five or six years M. Kessler's process for engraving on glass by means of hydrofluoric acid, of which various specimens, especially lamp-globes, may be seen anywhere in London. The results have been obtained with great economy by printing on paper the "*réserve*" or ground of the pattern with bitume de Judée dissolved in essence of turpentine; the printing is then transferred to the glass, which is plunged into a bath of hydrofluoric acid, in which a continual rotatory motion is given to it. The glass is acted on wherever there is no printing. When the engraving is sufficiently deep, the pieces are washed in an alkaline lye, which dissolves the *reserve*. This process has rapidly extended, and has already in great part displaced the ancient method of glass-cutting. In view of its increased consumption for this purpose, M. Kessler has simplified the manufacture of hydrofluoric acid, which he prepares in cast-iron cylinders. As a cure for the painful burns caused by this acid, he has found a certain antidote in binding on the wound strips steeped in acetate of ammonia.

On a New System of Evaporating Liquids. By M. L. Kessler.

There is at present an important gap in the list of apparatus for evaporating liquids. There are simple evaporators of various kinds, and there are arrangements in which the heat of the vapour from one liquid boils another more volatile liquid. There are also apparatus where the same effects are obtained by means of decreasing pressures corresponding to diminishing boiling-points, but not for the multiple evaporation of the same liquid without the intervention of decreasing pressures. This arises from the difficulty of condensing a vapour disengaged in the atmosphere, and necessarily of inappreciable tension, and especially mixed with air.

M. Kessler thinks that for resolving the question the first condition is the placing of the vessels above each other, so that the bottom of one shall be the cover of the other, as in this arrangement the air charged with vapour will easily ascend to be cooled in contact with the cover, then coming into contact with the liquid to be saturated with vapour it becomes the agent of its own transport. Constantly in motion, it cannot accumulate in the places for condensation and thus prevent the vapour from reaching these.

Secondly, to prevent the drops condensed from falling into the liquid below, he gives an inclination to the surface of the cover towards the sides all round. The drops adhering to the cover by capillary attraction drain into a trough round the outer edge of the lower vessel, and are thus delivered outside the apparatus. This trough also forms a water-lute between the two vessels.

M. Kessler says that such an apparatus performs the two separate operations of

distillation and evaporation. Used as an alembic, no refrigerator is required. By recent experiments by M. Iresca at the Conservatoire des Arts et Métiers, it was found that an apparatus of four vessels, of which the lowest was heated with gas, and the uppermost was open to the air and acted as a refrigerator, evaporated 15 litres of water with a cubic mètre of gas, while the same quantity of gas with a single vessel uncovered evaporated only 5·170 litres. The apparatus was 54 centimètres diameter, and evaporated nearly 4 litres an hour. When two vessels are used and the upper one is kept supplied with cold water, 20 litres of water an hour can be distilled.

For concentrating sulphuric acid, only the bottom vessel, or capsule, is required to be of platina.

In applying this apparatus to the evaporation of common salt, and especially carbonate of soda, M. Kessler has found that, in the atmosphere partly saturated with vapour under the inclined covers of the vessels, the salts crystallize on the bottom and sides in large crystals, as is the case in slow cooling. The solution of carbonate of soda does not produce a pellicle on the surface, and forms beautiful prisms containing 17 per cent. of water. Iodide of potassium gives crystals of an unprecedented size, and sulphate of soda gives anhydrous crystals.

Are Nitrogen and Carbonic Oxide the Oxide of Carbon in different Allotropic or Isomeric States? By H. Kilgour, *of Edinburgh.*

The author, it was stated, was making experiments with the view, if possible, of reducing nitrogen and carbonic oxide into the same substance. Hitherto, however, his results had been negative.

On the Manufacture of Earthenware at Newcastle. By* C. T. Maling.

The manufacture of white earthenware was introduced into this district by Mr. Warburton, at Carr's Hill Pottery, near Gateshead, about 1730 or 1740. Those works were very successfully carried on for seventy years, when they gradually declined, and in 1817 were closed. A small portion of the building is still used as a brown-ware pottery. The next manufactory was built by Mr. Byers, at Newbottle, in the county of Durham, about 1755, where brown and white earthenware still continue to be made. In 1762, Messrs. Christopher Thompson and John Maling erected works at North Hylton, in the county of Durham; their successor, Mr. Robert Maling, in 1817 transferred his operations to the Tyne, where his descendants still continue the manufacture. St. Anthony's, Stepney Bank, and Ouseburn Old Potteries were commenced about the year 1780 or 1790. Messrs. A. Scott and Co. and Messrs. Samuel Moore and Co. erected potteries at Southwick, near Sunderland, the former in the year 1789, the latter in 1803. The pottery carried on by Messrs. John Dawson and Co., at South Hylton, was built by them in 1800. The works of Messrs. John Carr and Sons, at North Shields, were erected in 1814. Messrs. Thomas Fell and Co. built St. Peter's Pottery in 1817. The establishment of Messrs. Skinner and Co., Stockton-on-Tees, dates from 1824.

There are now about twenty-five potteries in this district, of which on the Tyne six manufacture white and printed ware, four white, printed, and brown ware, and three brown ware only, employing 1200 people, and manufacturing yearly about 12,000 tons of white clay and 3000 tons of brown clay, and consuming in the process of manufacture about 34,000 tons of coals. On the Wear there are two potteries manufacturing white and printed ware, two white, printed, and brown ware, and two brown ware only, employing about 500 people, manufacturing yearly about 4000 tons of white clay, 1500 tons of brown clay, and consuming in the manufacture about 14,000 tons of coals. On the Tees there are four potteries, manufacturing white and printed ware, employing 500 people, manufacturing 5000 tons of white clay, and consuming 13,000 tons of coals. Two potteries at Norton manufacture brown ware; the particulars of their operations the author had not been able to obtain.

* This paper was drawn up by the author at the request of the Local Committee.

The potteries in this district, being situated upon navigable rivers, have great advantages over their inland competitors, Staffordshire and Yorkshire. The expenses on clay from sea-freight and inland carriage average 13*s.* per ton to Staffordshire, and 5*s.* per ton to this district; and in flints the advantage is still greater, in Staffordshire the average being 19*s.* per ton against 4*s.* 6*d.* per ton here. Coals, although a little dearer here per ton, are so much superior in quality that 80 tons of Newcastle coals are equal to 100 tons of Yorkshire or Staffordshire coals.

About 1858, Messrs. Skinner and Co., of Stockton-on-Tees, first applied Needham and Kite's patent filtering-press for expelling the surplus water from the slip, which had formerly been done by evaporation. This is a much cleaner and better process than the old system, and is now adopted by thirty or forty potteries in England and Scotland. With the exception of three potteries in this district and at Glasgow, machinery has been very little applied to the manufacture of earthenware, and even at these works not nearly to the extent to which it is capable of being profitably adopted. One manufactory on the Tyne, Ford Pottery, having the best machinery, supplies at least 80 per cent. of the jars used by confectioners for marmalade and jam, &c., in England and Scotland.

The description of goods manufactured in this district is that used by the middle and working classes, no first-class goods being made here. The principal markets, in addition to the local trade, are the Danish, Norwegian, German, Mediterranean, and London, for exportation to the colonies. The trade to the United States being so very small from here, the American war has affected this district less than any other.

On the Constitution and Rational Formula of Narcotine. *By* Dr. A. Matthiessen, *F.R.S.*, *and* G. C. Foster, *B.A.*

Chemists have been aware of the existence of narcotine, as one of the constituents of opium—the dried-up juice obtained from the capsules of the white poppy—since almost the beginning of the present century; and the remarkable properties of the numerous derivatives which it yields, when acted on by various chemical reagents, have caused it to be made the subject of several extended investigations. Still, the constitution of narcotine, and of the products derived from it, has not hitherto been explained; and even its elementary composition has remained so far doubtful that some chemists have admitted the existence of three or four distinct varieties, each differing in composition from the rest. In a paper published in the Philosophical Transactions for 1863, p. 345, the authors of this communication have shown that (adopting the atomic weights $C=12$, $H=1$, $O=16$, &c.) the composition of narcotine is represented by the formula $C^{22}H^{23}NO^{7}$, and is always the same. In the same paper they have shown that the composition of cotarnine is represented by the formula $C^{12}H^{13}NO^{3}$; so that the action of oxidizing agents upon narcotine may be expressed by the equation

$$\underset{\text{Narcotine.}}{C^{22}H^{23}NO^{7}} + O = \underset{\text{Cotarnine.}}{C^{12}H^{13}NO^{3}} + \underset{\text{Opianic acid.}}{C^{10}H^{10}O^{5}}.$$

They have there also described several new transformations of narcotine, cotarnine, and opianic acid, which it is necessary, for the understanding of what follows, to recapitulate briefly in this place:—

1. One molecule of narcotine, boiled with excess of hydriodic acid, yields three molecules of iodide of methyl.

2. Cotarnine, heated with hydrochloric acid, yields chloride of methyl and *cotarnamic acid*:—

$$\underset{\text{Cotarnine.}}{C^{12}H^{13}NO^{3}} + HCl + H^{2}O = \underset{\text{Cotarnamic acid.}}{C^{11}H^{13}NO^{4}} + \underset{\text{Chloride of methyl.}}{CH^{3}Cl}.$$

3. Cotarnine, heated with dilute nitric acid, yields methylamine and *cotarnic acid*:—

$$\underset{\text{Cotarnine.}}{C^{12}H^{13}NO^{3}} + 2H^{2}O = \underset{\text{Cotarnic acid.}}{C^{11}H^{12}O^{5}} + \underset{\text{Methylamine.}}{CH^{5}N}.$$

4. Nascent hydrogen converts opianic acid into meconin:—

$$\underset{\text{Opianic acid.}}{C^{10}H^{10}O^5} + H^2 = \underset{\text{Meconin.}}{C^{10}H^{10}O^4} + H^2O.$$

5. Opianic acid, boiled with strong potash-lye, yields meconin and hemipinic acid:—

$$\underset{\text{Opianic acid.}}{2C^{10}H^{10}O^5} = \underset{\text{Meconin.}}{C^{10}H^{10}O^4} + \underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6}.$$

6. Opianic acid, meconin, or hemipinic acid, boiled with hydrochloric acid, yields chloride of methyl.

7. In the case of hemipinic acid, the action of hydrochloric acid, if continued for a short time, gives rise to carbonic acid and a *new acid*, $C^8H^8O^4$, as well as to chloride of methyl:—

$$\underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6} + HCl = \underset{\textit{New acid.}}{C^8H^8O^4} + CO^2 + CH^3Cl;$$

or, if continued for a longer time, to *hypogallic acid*, carbonic acid, and chloride of methyl:—

$$\underset{\text{Hemipinic acid.}}{C^{10}H^{10}O^6} + 2HCl = \underset{\text{Hypogallic acid.}}{C^7H^6O^4} + CO^2 + 2CH^3Cl.$$

The object of the present communication is to point out analogies between the substances which take part in, or result from, these transformations and bodies whose constitution is better known; and so to deduce a series of rational formulæ which shall, as far as possible, express their respective chemical functions and their relations to one another.

Cotarnine.—The authors regard transformations 2 and 3 as proving that cotarnine is a methylized compound, corresponding to a not yet isolated *normal cotarnine*, $C^{11}H^{11}NO^3$, bearing the same relation to cotarnic acid that malimide bears to malic acid. They point out that cotarnic acid resembles malic acid in being a bibasic acid containing five atoms of oxygen, and they compare the derivatives of each as follows:—

$C^{11}H^{12}O^5$ Cotarnic acid.	$C^4H^6O^5$ Malic acid.
$C^{11}H^{13}NO^4$ Cotarnamic acid.	$C^4H^7NO^4$ Aspartic acid
$C^{11}H^{13}NO^4,HCl$ Hydrochlorate of cotarnamic acid.	$C^4H^7NO^4,HCl$ Hydrochlorate of aspartic acid.
$C^{11}H^{11}NO^3$ Cotarnimide (hypothetical normal cotarnine).	$C^4H^5NO^3$ Malimide.
$C^{11}H^{10}(CH^3)NO^3$ Methyl-cotarnimide (cotarnine).	$C^4H^4(C^6H^5)NO^3$ Phenyl-malimide.

Hence they deduce the following rational formulæ:—

$$\left.\begin{matrix}(C^{11}H^9O^2)^{iii}\\ H^3\end{matrix}\right\} O^3 = \text{cotarnic acid (bibasic but triatomic).}$$

$$\left.\begin{matrix}(C^{11}H^9O^2)^{iii}\\ H^4\end{matrix}\right\} \begin{matrix}O^2\\ N\end{matrix} = \text{cotarnamic acid.}$$

$$\left.\begin{matrix}(C^{11}H^9O^2)^{iii}\\ CH^3H\end{matrix}\right\} \begin{matrix}O\\ N\end{matrix} = \text{methyl-cotarnimide} = \text{cotarnine.}$$

Meconin, Opianic acid, Hemipinic acid.—Transformations 6 and 7 may be taken as proof that each of these bodies is a dimethylized derivative of a corresponding normal compound not yet isolated. The authors further regard transformations 4 and 5 as indicating the existence of a hydrate of meconin, $C^{10}H^{12}O^5$, and they suppose this compound to be a first result of both transformations, and to give rise to meconin by subsequent loss of the elements of water. If this be admitted, opianic acid and its congeners may be compared to oil of bitter almonds and glucose and their respective derivatives:—

$C^{10}H^{10}O^4$ Meconin.	C^7H^8 Benzylene.	$C^6H^{12}O^5$ Mannitan.
$C^{10}H^{12}O^5$ Hydrate of meconin (hypothetical).	C^7H^8O Benzylic alcohol.	$C^6H^{14}O^6$ Mannite.
$C^{10}H^{10}O^5$ Opianic acid.	C^7H^6O Oil of bitter almonds.	$C^6H^{12}O^6$ Glucose.
$C^{10}H^{10}O^6$ Hemipinic acid.	$C^7H^6O^2$ Benzoic acid.	$C^6H^{12}O^7$ Mannitic acid.

These comparisons lead to the following rational formulæ :—

$$\left.\begin{matrix}(C^8H^4O)^{iv}\\(CH^3)^2H^2\end{matrix}\right\}O^4 = \text{hypothetical hydrate of meconin.}$$

$$\left.\begin{matrix}(C^8H^4O)^{iv}\\(CH^3)^2\end{matrix}\right\}O^3 = \text{meconin.}$$

$$\left.\begin{matrix}(C^8H^2O^2)^{iv}\\(CH^3)^2H\end{matrix}\right\}\begin{matrix}H\\O^3\end{matrix} = \text{opianic acid.}$$

$$\left.\begin{matrix}(C^8H^2O^2)^{iv}\\(CH^3)^2H^2\end{matrix}\right\}O^4 = \text{hemipinic acid.}$$

Combining the above formula for meconin with that previously arrived at for cotarnine, the authors give the following as the rational formula of narcotine :—

$$\begin{matrix}CH^3\\(C^{11}H^9O^2)^{iii}\\(C^8H^4O)^{iv}\\(CH^3)^2H\end{matrix}\begin{matrix}\}N\\\}O\\\}O^3\end{matrix}$$

—believing that by it all the known transformations of narcotine and of its immediate products of decomposition can be expressed.

Short Communications on Galvanic Copper, Photolithography, and Photomicroscopic Specimens. By M. l'Abbé Moigno.

On a Deposit in the Gas-tubes of the Cleveland Blast Furnaces. By J. Pattinson.

A substance, in fine powder, varying in colour from blackish-grey to almost white, is deposited in the large tubes used for conveying the waste gases of iron-smelting furnaces to the boilers and heating-stoves, where they are economized. The deposit at present in question had been found in the tube of a furnace smelting a mixture of Upleatham and Rosedale ironstones with Weardale blue limestone and South Durham cokes. The deposit was of a dark-grey colour, and was impalpably fine. Analysis determined its constituents as follows:—

Protoxide of iron	14·22	per cent.
Oxide of zinc	10·48	„
Sulphide of zinc	13·70	„
Alumina	8·20	„
Lime	12·32	„
Magnesia	5·03	„
Chloride of sodium	4·74	„
Ammonia	0·70	„
Thallium	trace	„
Sulphuric acid	3·18	„
Free sulphur	0·17	„
Silica	22·60	„
Carbonaceous matter	4·50	„
	99·84	

On Zinc, Nickel, and Cobalt in the Cleveland Ironstone. *By* J. PATTINSON.

The constant presence of oxide of zinc in considerable amount in the deposit found in the waste gas-tubes of blast furnaces smelting Cleveland ironstone had pointed out that zinc was probably uniformly diffused in this ironstone. In order to ascertain this, the author obtained a sample from the main seam of the Upleatham mines, and, after examining it carefully to see that it contained none of the visible pieces of zinc-blende which are occasionally found, sought for the presence of zinc in the usual manner. From this sample an amount of oxide of zinc equal to 0·32 of a grain of zinc per lb. of ironstone, or about 10 grains per ton, was obtained. In searching for zinc, indications of the presence of nickel and cobalt were also obtained. A quantitative analysis showed that the ironstone contained 0·72 of a grain of nickel, and 0·12 of a grain of cobalt, per pound. In smelting, the principal portion of these two metals will be reduced to the metallic state and will accompany the iron, although it is probable that the peculiar bluish colour which the furnace slag sometimes possesses may be partly owing to minute quantities of cobalt carried away with the slag. The author has estimated the amounts of nickel and cobalt contained in pig iron, malleable iron, and puddling furnace cinder, all of which were produced from Cleveland ironstone. In each case four ounces of the sample were operated upon. They contained as follows:—

	Pig Iron.	Malleable Iron.	Puddling Furnace Cinder.
Grains of nickel per lb.	1·88	1·56	0·313
Grains of cobalt per lb.	0·32	0·24	0·062
Percentage of nickel	0·027	0·022	0·0045
Percentage of cobalt	0·004	0·003	0·0009

The samples were taken at different periods of time, and from entirely different batches of iron. An admixture of nickel with iron is said to improve the quality of the latter; but it is scarcely probable that either nickel or cobalt in the above proportions will affect the quality of the iron appreciably. These results are interesting, however, as affording another illustration of the wide diffusion throughout nature of comparatively rare substances.

On the various kinds of Pyrites used on the Tyne and Neighbourhood in the Manufacture of Sulphuric Acid. *By* J. PATTINSON.

Iron pyrites, or bisulphide of iron, has been used on the Tyne in the manufacture of sulphuric acid since about the year 1840. At that time, and up to 1856, the only supplies of this mineral were obtained from Ireland, Cornwall, and the col-

	1.	2.	3.	4.	5.	6.	7.
Sulphur	44·60	49·30	45·01	45·60	44·50	44·20	38·10
Iron	38·70	41·41	39·68	38·52	39·22	40·52	34·44
Copper	3·80	5·81	..	..	1·80	0·90	trace
Lead.....................	0·58	0·66	0·37	0·64	..	1·50	..
Zinc	0·30	trace	1·80	6·00	1·18	3·51	..
Thallium	trace	trace	trace	trace	..	..	..
Lime.....................	0·14	0·14	0·25	0·11	2·10	0·24	4·96
Magnesia	trace	trace	..	..	0·01	..	0·33
Carbonic acid	..	..	..	..	1·65	..	5·11
Arsenic..................	0·26	0·31	trace	trace	..	0·33	trace
Oxygen...................	0·23	0·25	0·32	0·37	0·45	0·25	0·31
Coal and loss	..	..	..	..	..	..	14·45
Gang	11·10	2·00	12·23	8·70	9·08	8·80	1·40
Moisture	0·17	0·05	0·25	0·36	0·17	0·90	0·90
	99·88	99·93	99·91	100·30	100·16	100·34	100·30

ieries of this district, where it occurs and is associated with coal, and is known by the name of coal brasses. But since 1856 other and more abundant supplies have been obtained from Spain, Portugal, Belgium, Westphalia, Norway, Sweden, and Tuscany. At present the total consumption of pyrites on the Tyne and neighbourhood is about 70,000 tons per annum, representing a value of about £105,000. The preceding Table represents the composition of the principal kinds of pyrites at present used. The samples analyzed are chiefly fair average samples of cargoes brought to the Tyne.

No. 1. Spanish pyrites, obtained from the districts of Huelva in Spain and Algarve in Portugal. About 30,000 tons per annum used on the Tyne. No. 2. Ditto. No. 3. One of the Belgian varieties, obtained from the Rocheux mine, Theux, near Spa. About 12,000 tons of Belgian pyrites used on the Tyne per annum. No. 4. Westphalian pyrites. Consumption on the Tyne about 8000 tons per annum. This is one of the most abundant sources of the newly-discovered metal thallium. No. 5. Norwegian pyrites, obtained from the island of Ytteröen, in the Bay of Drontheim. About 6000 tons per annum used on the Tyne. No. 6. A rich variety of Irish pyrites, obtained from the Wicklow mines. About 4000 tons of Irish pyrites used on the Tyne per annum. No. 7. Coal brasses, sample obtained from the Walker Colliery. About 7000 tons per annum used on the Tyne for the manufacture of sulphuric acid. Other analyses of pyrites were also given in the paper. The process adopted by the author in estimating the amount of sulphur, the methods of burning, the treatment of the residuum, and various objectionable varieties of pyrites were also described.

On a New Method of Measuring the Chemical Action of the Sun's Rays. By Dr. T. L. Phipson.

The author happened to notice that a solution of sulphate of molybdic acid (that is, a solution of molybdic acid in excess of sulphuric acid) standing in his laboratory upon a shelf which is partly exposed to the sun for about three hours each day became bluish green in the daytime and colourless again at night.

In sunlight...... $MoO^3+HO=MoO^2+HO^2$

At night........ $MoO^2+HO^2=MoO^3+HO$.

This change is produced by the chemical action of the sun's rays: heat will not effect it; for the solution boiled did not change colour.

Nothing is easier than to measure with the greatest accuracy *the amount of reduction which takes place by the sun's action in a given time.* The actinometric liquid is prepared by dissolving molybdate of ammonia in excess of sulphuric acid, introducing metallic zinc until the liquid becomes dark blue, and then adding a solution of permanganate of potash until the last drop restores the liquid to its primitive colourless state. A provision of the liquid having been made, twenty cubic centimetres are exposed to the direct rays of the sun for one hour (11 to 12) each day. It is then withdrawn, and the amount of reduction measured by a standard weak solution of permanganate of potash. This is delivered from a pipette with bulb and long thin stem, graduated into 100 equal divisions. After each insolation, the degree read off the pipette gives for each day the relative amount of actinism, just as a thermometer gives the degrees of heat.

From a short series of experiments, it appears that the variation of the chemical action of the sun's rays describes curves which are not only irregular, but present sometimes sudden deflections, calling to mind barometric curves, to which they may perhaps be related.

On Musical Sounds produced by Carbon. By Dr. T. L. Phipson.

When a rod of glass is suspended by a string, and struck with a hammer, it emits a beautiful musical sound—a fact turned to account in the instrument called the Harmonica. The same happens with phonolite, certain varieties of flint, and a few other minerals. In quarrying mountain-limestone, wedges are driven into holes drilled in the rock in order to break it; and the author noticed once, in Belgium, that the instant a slab separates in this manner, a peculiar musical sound shoots through it. Among the elements, none are perhaps more remarkable in

this respect than aluminium; a bar of this metal, suspended by a string and struck with a hammer, emits a musical sound like that of glass. He finds that the same occurs with compact homogeneous wood-charcoal. The best piece experimented on was 11 inches long, ½ inch wide, and weighed exactly 82·05 grammes. When struck, it gave the high treble C; and a piece weighing 2·05 grammes being struck off it, it gave the C sharp exactly. The note of the scale produced in these circumstances depends on the square of the length and the diameter of the substance struck; the duration of the sound, upon the duration of vibration produced by the shock. *Cæteris paribus*, glass will ring after a blow 4 to 5 seconds, aluminium 3 to 4 seconds, and charcoal 1½ to 2 seconds, according to his experiments. The densities of these three substances are somewhat similar:—

Glass	2·49
Aluminium	2·62
Amorphous carbon	2·50

It appears that some years ago a performer at Astley's Theatre executed a piece of music upon fragments of charcoal of different dimensions, suspended on strings.

On the Constant Increase of Organic Matter in Cultivated Soils. *By* Dr. T. L. Phipson.

On January 6th, 1863, an article appeared in 'The Times,' entitled "Exhaustion of Vegetable Mould," followed by a "leading article" upon the same subject, in which the writers stated that the organic matter of soils under cultivation is being constantly exhausted, that the vegetable mould is a most valuable constituent of soils, and that its loss is not replaced in any way in our present systems of agriculture. The author refutes these extraordinary statements by bringing forward the determination by analysis of the proportion of organic matter in soils submitted to culture for many years, compared with the quantity present in uncultivated soils; and, supported likewise by the opinions of the late Professor Johnston and Baron Liebig, he proves that *the organic matter of soils constantly increases by cultivation, whilst their fertility steadily decreases,*—this fact being due to the constant loss of potash, lime, phosphoric acid, &c.

The vegetable mould or humus supplies chiefly carbonic acid; but as plants get abundance of this in the air and water they absorb, that given by decomposition of humus constitutes in most cases an excess. A certain amount of organic matter in a soil generally betters the physical condition by rendering it more porous, &c. The author insists also on the necessity, in analyses of soils, of determining the amount of moisture by heating the soil to 105° C. as long as it loses weight, before proceeding to determine the amount of organic matter present.

Researches on the Manufacture of Prussiate of Potash. By the late John Lee *and* Thomas Richardson, *M.A., Ph.D., F.R.S.E., M.R.I.A., &c.*

The celebrated manufacturing experiment of Messrs. Bramwell and Hughes to obtain cyanogen from the nitrogen of the air and charcoal, induced the authors to examine the old process of producing prussiate of potash, in order to ascertain what became of the nitrogen of the animal matter.

The experiments were all made with the same mixture of materials, which was formed of pure horn finely rasped, potash, and clean iron filings. A small quantity of water was added to assist in making an intimate mixture, which was afterwards carefully dried, and then ground to a fine powder. This mixture was composed of

Horn	16·00
Potash	17·72
Iron	3·00
Moisture	3·28
	40·00

A potash-charcoal was made by soaking 13 ozs. of wood-charcoal with a solution of 4 ozs. of potash, and then fully dried.

A gun-barrel was partially filled with the first mixture and exposed to a red heat in a separate furnace. In the first and second series of experiments the gases produced in the gun-barrel were passed through the potash-charcoal, which was kept at a red heat in another iron tube in connexion with the gun-barrel. In the third series of experiments the gases were passed through hydrochloric acid; in the fourth series of experiments the gases were passed through the red-hot potash-charcoal, and then, successively, through hydrochloric acid and a solution of potash. In this series of experiments the gases which escaped were collected and analyzed.

The prussiate of potash which was formed was extracted and crystallized. The ammonia was estimated by means of platina, and afterwards calculated into the equivalent of prussiate of potash.

The theoretical yield of prussiate of potash was 382·50, and the results of the experiments are shown in the following Table:—

	1.	2.	3.	4.
From the retort............	101·97	135·46	146·93	141·08
From the tube	68·25	63·54	..	71·00
From the hydrochloric acid..	..	..	140·24	58·80
From the potash	..	..	..	2·75
Total prussiate ....=	170·22	199·00	287·17	273·63
Loss.............=	212·28	183·50	95·33	108·87
Produce per cent. ..=	44·5	52·2	75·1	71·5

The gases evolved in the fourth series were collected after the experiment had been some time in operation, and consisted of—

Nitrogen	14·00
Hydrogen	46·00
Carbonic oxide	25·34
Carburetted hydrogen	14·66
	100·00

It therefore follows that a quantity of the nitrogen is lost in consequence of its being isolated; but the principal source of loss in the process arises from this substance escaping in the form of ammonia.

On the Separation of Lead and Antimony.

By THOMAS RICHARDSON, *M.A., Ph.D., F.R.S.E., &c.*

The hard or slag leads of commerce are softened in the following manner:—A quantity of the lead is melted in large shallow metal pans, and exposed to a current of hot air; the antimony, alloyed with a certain quantity of lead, becomes oxidized, and the dross which is formed floats on the surface, whence it is skimmed off by the workman. The lead which remains is now soft and malleable, and nearly free from antimony.

When the dross is reduced to the metallic state, it may be submitted to the same process, when a further separation of lead takes place. The dross from the second calcination contains the lead and antimony in about equal proportions, beyond which this process of calcination cannot be carried.

The following analyses show the changes which take place in these operations:—

ENGLISH HARD LEADS.

	Original Lead.	First Calcination.	Second Calcination.
Lead	99·27	86·53	52·84
Antimony	0·57	11·29	47·16
Copper	0·12	trace	trace
Iron	0·04	0·34	trace
	100·00	98·16	100·00

SPANISH HARD LEADS.

	Original Lead.	First Calcination.	Second Calcination.
Lead	95·81	64·98	56·60
Antimony	3·66	29·84	43·40
Copper	0·32	5·90	traces
Iron	0·21	0·20	traces
	100·00	100·92	100·00

The author has found that the addition of a small quantity of soda ash to the dross, in the process of reduction, acts very beneficially; and as it enables the workman to work at a lower heat, a quantity of antimony is saved. This action is illustrated by the following analyses:—

	Without Soda Ash.	With $2\frac{1}{2}$ per cent. Soda Ash.
Lead	82·88	58·70
Antimony	16·09	40·66
Copper	0·68	0·32
Iron	0·35	0·32
	100·00	100·00

The alloy of antimony and lead obtained in this process answers very well in the preparation of type furniture.

In these operations a quantity of refuse products accumulate in the smelting works, which are reduced in small blast furnaces; and after some time the hearth of these furnaces is gradually filled with a spongy semifused mass, called a *Cuesco* by the Spaniards. One of these masses was analyzed, and found to contain

Lead	61·35
Antimony	29·50
Copper	8·30
Iron	0·61
Nickel	traces
	99·76

On the Use of Fuel in Marine Boilers.

By THOMAS RICHARDSON, *M.A., Ph.D., F.R.S.E., &c., and* T. W. BUNNING.

The object of these experiments was to examine the effects produced by mixing coals of different characters.

As regards the use of fuel in raising steam, coals may be divided into non-bituminous, semibituminous, and bituminous. The two latter cannot be burnt with close fire-doors without the formation of smoke, while the former require a peculiar stoking to obtain a maximum evaporative effect.

In conducting the experiments at Her Majesty's Dockyard at Keyham, the character of the smoke was recorded according to the following scale:—

No. 1	Very light.
2	Light.
3	Light brown.
4	Brown.
5	Black.
6	Very black.

The experiments lasted six hours on an average, so that the greatest number of marks which could have been recorded against any coal was 2160.

When Hartley coal was burnt with close doors, the number recorded was 292, and against Welsh coal (Gellie Cadoxtan) the number was 40.

When these coals were mixed in equal quantities and burnt in the usual manner with close doors, the number recorded was only 1.

The details of these experiments were given in Tables, and the extraordinary fact is thus found, that a mixture of these two coals can be burnt in an ordinary steam-boiler furnace, with the usual stoking, without producing the smallest smoke.

Another series of experiments has been made, which confirm the above obser-

vations, and the following Table contains some of the results, which possess more general interest:—

Coal.	Lbs. of water evaporated from 100° F. by 1 lb. of coal.	Cubic feet of water evaporated per sq. foot of grate.
Hartley	10·71	4·10
Welsh Aberdare	10·14	3·7
Hartley and Welsh round coal mixed in equal quantities	10·45	3·7
Hartley round coal and Welsh dust coal mixed in equal quantities	9·93	3·45

Analysis of a Deposit from a Colliery Water containing Sulphate of Baryta. By THOMAS RICHARDSON, *M.A., Ph.D., F.R.S.E., &c.*

In the year 1849 a spring of water made its appearance in the shaft of Walker Colliery, which Mr. Clarke, the mining engineer, carried off by means of a wooden pipe. The water was quite clear as it issued from the sides of the shaft, but it rapidly deposited a solid matter which soon filled the pipe. This deposit contains a large quantity of sulphate of baryta, as indicated by the following analysis:—

Sulphate of baryta	90·01
Sulphate of lime	3·04
Peroxide of iron	·30
Silica	2·65
Water	3·51
	99·51

After the lapse of a short time the deposit ceased to form, and the author had no opportunity to examine the water. The water most probably contained the baryta in some lower form, which absorbed oxygen as the solution fell down the pipe to the bottom of the shaft.

On the Chemical and Physical Principles in connexion with the Specific Gravity of Liquid and Solid Substances. By OTTO RICHTER, *Ph.D.*

In this paper the author endeavours to show that chemistry has for its foundation not a simple, but a complex principle. On the one hand, it is the purely chemical principle, whatever its nature may be, which determines the various forms of molecular arrangement; and it is the ponderable portion alone of the various kinds of atoms which, in their constant weight-equivalents, furnishes the basis of calculation. On the other hand, it is the purely physical principle, whatever its nature may be, which determines the specific volume of the molecules; and it is the imponderable portion alone of the various kinds of atoms which, in their variable volume-equivalents, furnishes the basis of calculation. Accordingly our tree of chemical knowledge splits up into two main branches, viz., *Pondo-Chemistry* and *Impondo-Chemistry*. The author believes that all the chemical elements consist, not of single atoms, but of a definite number of such atoms associated according to some fixed principle of grouping, and thinks that all the modifications in the physical properties of matter, which we are in the habit of distinguishing by the terms polymorphism, allotropism, specific heat, fusing- and boiling-points, crystalline form, optical and electro-magnetic polarity, &c., ought to be considered as so many functions of one and the same variable magnitude, viz., the specific volume. He imagines, moreover, that the eighth part of the volume of ice, which Playfair calls the Unit Volume, is really the standard whereby all the volume-equivalents will one day be correctly measured and calculated. The specific volume he regards as the resultant of the combined repulsive energies proper to the various species of molecules, and holds that these repulsive energies are directly proportional to the amount of vibratory movements developed in the system. These energies he supposes to vary in range and intensity correlative

with the more or less partial suspension (paralysis) of these vibratory movements, and considers that all the endless modifications in the physical and, to a certain extent also, chemical deportment of molecules ought mainly and exclusively to be referred to paralytic agency; and by no means, as is commonly maintained on the part of our most distinguished experimentalists, to certain alterations in the form of atomic grouping. Thus, *e. g.*, M. Pasteur, in order to explain the phenomena of circular polarization, at one time assigns as the primary cause of that property the unsymmetrical grouping of the atoms at two opposite regions of the influencing molecule; at another time, when discussing the case of chlorate of soda and its congeners, which are optically active in the crystalline state, but entirely neutral when in solution, he assigns a primary cause very different and even specifically distinct from the former, namely, the spiral form of aggregation, which form, being destroyed in the act of solution, leaves the individual molecules optically, because constitutionally, inactive. The author thinks it unphilosophical to attempt an explanation of this class of phenomena, and which are in every respect so identical, by means of two first causes, so essentially distinct both in their form and in their mode of action (the one being purely mechanical, and the other purely dynamical), and believes that circular polarization ought, on the contrary, to be referred, not to the existence of *chemical*, but of *physical dissymmetry*, and that the reason why chlorate of soda loses its optical energy in the act of solution must be sought in the varying temperature and the altered state of aggregation, which cooperate in restoring the *physical symmetry*, while the process of crystallization tends to produce the opposite effect.

In conclusion, the author states that for the last twelve years he has been engaged in composing a catalogue of the specific gravities of liquid and solid substances; but he regrets to find that, with the most ample resources at his disposal, the collection still amounts to so small a fraction, in comparison with the immense number of non-determined substances, that he feels himself justified in urging upon the British Association the adoption of some practical measure.

On Titanium in Iron. *By* Dr. Riley.

This metal, the author observed, appeared in small cubical crystals, and had long been observed in blast furnaces used for making the best grey iron. Titanium ought no longer to be considered one of the rarer elements, as it occurs very generally, and is a constituent of clay. Stourbridge bricks contained at least 1·05 per cent. of it. In mining-shales as much as 3 or 4 per cent. have been traced. The object of the paper was to show that, under certain conditions, it formed a constituent part of pig iron, and its presence appeared to have some beneficial effects in the manufacture of iron and steel, as it acted somewhat similarly to manganese.

On Glass.* *By* R. W. Swinbourne.

The paper treated at length on plate, crown, sheet, flint, and bottle glass. It is worthy of remark that ordinary window glass was first used in Great Britain for architectural purposes at the great monasteries at Monkwearmouth, on the river Wear, and at Jarrow, on the Tyne. The venerable Bede, our first ecclesiastical historian, who flourished at the former place in the seventh century, relates that his cotemporary, the Abbot Benedict, sent for artists beyond seas to glaze the Monastery of Wearmouth. Such was the change made in their churches by the use of glass instead of other and more obscure substances for windows, that the unlettered people avowed a belief, which was handed down as a tradition for many generations, "that it was never dark in old Jarrow Church." By a singular coincidence, the first manufactory of window or crown glass in Great Britain was established at Newcastle-upon-Tyne within a few miles of these monastic establishments. In the year 1616, Admiral Sir Robert Maunsell erected glass-works at the Ouseburn, Newcastle, which were carried on without interruption till nearly the middle of the present century. Crown window glass is no longer made on the Tyne, and as an art it is declining everywhere; but the manufacture of sheet glass has of late years been most largely increased, and is carried on to a great extent in the ad-

* This paper was drawn up by the author at the request of the Local Committee.

joining district of the river Wear, where the quantity produced by Messrs. James Hartley and Co. alone is very nearly equal to the entire produce of the six extinct crown-glass manufactories on the river Tyne. The beautiful art of coloured glass, or what is termed stained glass, has been carried on most successfully for some years in Newcastle by Mr. William Wailes and others; and the tasteful designs and beautiful colouring of Mr. Wailes's numerous works have given him a great celebrity throughout the kingdom. A great improvement has been made in this description of glass, inasmuch as exterior staining has been superseded by glass made of the required tint in the crucible of the manufacturer. The glass, therefore, is not stained, but is inherently of its peculiar colour. This process of making coloured glass in the crucible has restored the art to its pristine state, for in such manner this glass was made by the old masters. By its means the brilliancy and durability of the old coloured glass has been obtained, and all the colours of antiquity are produced by our modern manufacturers in greater brilliancy, ruby alone excepted. It is ascertained that there is something in the undulating and imperfect surface of the glass of the fourteenth century which renders it more adapted to display intensity of colour than the more perfect glass of modern times. Hence the coloured-glass makers resort to the use of a glass, as the basis of their colour, which of itself is of the most rude and imperfect character.

The manufacturers of window glass on the river Tyne have originated many improvements in the process. In 1817 Mr. Charles Attwood, of this town, made crown glass by using the insoluble part of kelp, separated by lixiviation from its saline ingredient, which he rejected, and in its place he used the carbonate of soda of commerce. The analytical examination of this insoluble portion of kelp was undertaken in 1829 by the *employés* of a large crown-glass manufacturer at South Shields, with the assistance of the late eminent Dr. Turner, of the London University; and, after a long series of experiments, most seriously impeded by the excise duty and regulations, it was discovered that kelp in any form might be safely abandoned, and that better results with a great saving could be obtained by the use of lime and carbonate of soda. The alkaline ingredient in plate glass was for many years obtained from the Barilla, from Alicant, or Teneriffe, and was superseded by an alkali prepared by Lord Dundonald, by the decomposition of common salt by carbonate of potash—carbonate of soda and chloride of potassium being the results. The latter was separated by priority of crystallization; and, the remaining liquor being evaporated, carbonate of soda was obtained in a solid state, and was so used by the plate-glass maker. This process was used in England up to the year 1832, when it was discontinued at the Plate Glass Works at South Shields. Carbonate of soda of commerce, in a refined state, at less than half the price, was substituted, and its use has become general throughout England.

A New Form of Gas-Battery. *By* W. SYMONS, *F.C.S.*

In Grove's well-known gas-battery, as stated by the author, the greater part of the electrical action is developed at the line where the platinum, liquid, and gas come into contact; thus a very small portion of each platinum plate is efficiently employed. At the Glasgow Meeting of the Association, the author exhibited a battery of his construction, in which a much greater portion of the platinum was brought into action; but the battery now shown is far more compact and simple. The object is to render available the longest section of the platinum; thus, in using plates four inches long and half an inch wide, instead of having a line of action one inch long, by the arrangement now proposed the active portion will be two lines of eight inches each; thus increasing it from one inch to sixteen. An arrangement is required to keep up the supply of gas, which is done by communicating with a reservoir through glass tubes, connected by india-rubber joints with each cell. Small siphons are also arranged to keep the liquid in each cell at a uniform level.

On the Composition of some New Zealand Lignites. *By* MURRAY THOMSON, *M.D., F.R.S.E.*

In general appearance these lignites are more like common coal than any other samples of *brown coal* that the author has ever seen. Some of them are compact

and difficult to break, and when broken, showing a conchoidal or semi-conchoidal fracture. Others, again, are very brittle, and exhibit a cubical or even fracture. The streak in all the samples is dark brown. It is only here and there through the masses that they show any traces of woody tissue. The mean specific gravity of six of the samples is 1·340. These characters, when taken along with their chemical composition, would place these lignites in the variety of the earthy brown coals.

In composition and in economic value, whether regarded as fuel or as sources of gas or oil, the Table which accompanies this paper shows that the New Zealand lignites are greatly inferior to the coals of the carboniferous formation of any country; and especially are they inferior in the somewhat large amount of ash which they contain. When, however, compared with other lignites, they must be regarded in a favourable light.

New Zealand Lignites.

(The quantities are those contained in one ton.)

Designation.	Volatile matter.	Coke.	Fixed Carbon.	Ash.	Gas.	Oil.	Sp. gr.
	lbs.	lbs.	lbs.	lbs.	cub. ft.	gallons.	
Saddle Hill (Otago) Lignite. No. 2.	1267	972	887	85	2954	17	1·262
Saddle Hill (Otago) Lignite. No. 3.	1194	1046	964	82	3175	15½	1·195
Saddle Hill (Otago) Lignite. No. 6.	1140	1099	733	366	1889	..	1·626
Saddle Hill (Otago) Lignite. No. 8.	1217	1021	659	362	3175	..	1·147
Saddle Hill (Otago) Lignite. No. 9.	977	1262	681	586	3024	7½	1·337
Abbot's Creek Lignite	1170	1068	737	331	3024	..	1·496
M'Coll's " "	1296	943	632	303	3931		
Clutha " "	1378	861	787	73	3250		
Ennerglyn (Nelson) Coal?	1266	973	911	62	4400		
Lignites from other places.							
Provence (15 samples)	1097·6	864·6	589·1	275·5			
Hesse Cassel (5 samples) ..	963·2	1187·2	1099·2	88·3	..	..	1·37
Wigan	..	..	..	111·00			
South American (3 samples)	..	..	..	206·00	..	..	1·30
24 samples of German Lignites yielded on an average 18 gallons of crude oil per ton.							

Définer par la Végétation l'État moléculaire des Corps. Analyser la Force végétale par des Essais raisonnés de Culture. By M. G. VILL.

On the Oxidation of Beta-Hexylic Alcohol. By Professor WANKLYN, *F.R.S.E.*

This paper contained an account of some researches by the author and Dr. Erlenmeyer "On the Oxidation of Beta-Hexylic Alcohol." Beta-hexylic alcohol—the alcohol which was obtained from mannite, and which belongs to a new series of alcohols isomeric with the alcohols of the vinic series, but differing widely from them in properties and reactions—is easily oxidized by a mixture of bichromate of potash and dilute sulphuric acid. Its first product is beta-hexylic aldehyd, thus:—

$$\beta C_6H_{14}O + O = \beta C_6H_{12}O + H_2O.$$

The next products are carbonic acid, water, and butyric acid, thus:—

$$\overbrace{\beta C_6H_{12}O}^{\text{Hexylic Aldehyd.}} + O_7 = 2CO_2 + 2H_2O + \overbrace{C_4H_8O_2}^{\text{Butyric Acid.}}.$$

The interest attached to this decomposition depends upon its furnishing a proof that two atoms of carbon in the beta-alcohol are differently combined from the remaining four.

In the normal or alpha-alcohol the first stage of oxidation is the production of the aldehyd,

$$aC_6H_{14}O+O=aC_6H_{12}O+H_2O.$$

The second stage, the production of the corresponding fatty acid,

$$aC_6H_{12}O+O=\overbrace{C_6H_{12}O_2}^{\text{Caproic Acid.}}.$$

It would seem that, while in the alpha or common series of alcohols the union of the carbon atoms with one another is quite regular, the reverse obtains in the beta series.

On Fractional Distillation.

By J. ALFRED WANKLYN, *Professor of Chemistry in the London Institution.*

Fractional distillation is resorted to in order to separate the single liquids which are present in a mixed liquid. The phenomena which take place during the distillation of a mixture are of a very complex order, and the general conditions which concur to produce the result may be enumerated as follows:—

1. Composition of the mixture, *i. e.*, relative proportion of the individual liquids present.
2. Tensions of the vapours of the individual liquids at the boiling-point of the mixture.
3. Densities of the vapours.
4. Latent heat of the individual vapours, and capacity of the individual liquids for heat.
5. Diffusion-coefficients of the individual vapours.
6. Rate of distillation.
7. Adhesions between the liquids.

Whenever a mixed liquid distils off so as to yield a vapour different in composition from the initial liquid, it is obvious that separation is taking place; and if the vapour is *continuously* different in composition from the initial liquid, perfect separation is the inevitable result if the process be pushed far enough.

The author considers each of the above-named *general conditions* first separately, and then in conjunction with the rest. The *rate* of *distillation* he believes to be of particular importance, for that determines whether the individual liquids shall distil off mainly according to the tension of their vapours, or mainly according to the diffusion-coefficients of their vapours. Finally, he expresses his belief that by a proper regulation of the distillatory process any mixture whatever may be completely separated into its individuals.

On Oxidation by Ozone. *By* Dr. T. WOOD, *F.C.S.*

Accepting the fact that oxygen is capable of existing in more than one form, he called attention to the difference between the action of ordinary oxygen and the kind of oxygen which is commonly known as ozone. The results of his experiments went to show that ozonized air is capable of supporting combustion more powerfully than common air. Ozone was also a most powerful disinfectant. It entirely removed the smell of ammonia and sulphuretted hydrogen from decomposed blood, and recoagulated the fibrine after it had been dissolved by the ammonia generated during decomposition. At a temperature of 70° F. milk was most easily curdled in ten minutes by ozone; albumen and fibrine are not decomposed by ozone. Quills soaked in dilute acetic acid form excellent joints for apparatus in experiments with it. The author stated that in the neighbourhood of stables and such like places, ozone was never to be found in warm weather, and concluded with a few remarks on the antiseptic properties of ozone below 60° F.

On Impurities in Lead and Molecular Motion. *By* Dr. ZENNER.

This communication referred to a peculiar effect of molecular motion in separating impurities from metals—lead being instanced. The author classified the con-

ditions and forms under which the forces which cause these motions are exerted, and under which such phenomena exhibit themselves, as follows. First, when the substances have to be brought into a fluid state by dissolving them in water, alcohol, &c., for the purpose of crystallization or for dialysis, as shown by the beautiful researches of Professor Graham. Secondly, when the substances are brought into a fluid state by heat, as is usually done with metals, such as lead, antimony, &c., when it is intended to crystallize them for their purification; but the most remarkable instances are those in which the motion of molecules takes place without there being such facilities afforded to the mobility, as in the previous division, the substance remaining in a solid state. The third division was where the change was produced by mechanical means, as is shown by the change of malleable fibrous iron by means of concussion into a crystalline and brittle form. Fourthly, the existing cause may be chemical action, of which hitherto only a few, but those very interesting, instances have been noticed. Another instance of molecular motion under the excitement of chemical action observed in the manufacture of white lead by the Dutch process, as used in this country, is the object of the paper. Thin sheets of metallic lead are exposed at a temperature rarely exceeding 180° Fahr. to the action of the atmospheric air, mixed with the vapour of acetic acid and carbonic acid. They are converted into carbonate of lead; but when the lead used for this purpose has not the necessary purity, there are observable in the parts oxidized and converted into carbonate of lead layers of different tints, and especially the thin layer nearest to the remaining portion of metallic lead shows a decided difference in colour, being darker and generally of a reddish-grey hue, arising from the oxides of iron, copper, &c.; and the remaining portion of the metallic lead, on being analysed, also showing an increase of the impurities.

GEOLOGY.

Address of the President, Warington W. Smyth, *M.A., F.R.S., F.G.S., Chief Inspector of the Minerals of the Crown and of the Duchy of Cornwall, Lecturer at the Royal School of Mines, Jermyn Street.*

If there is any one part of the British Islands where the very name of the place is naturally associated in our minds with a particular geological formation, it is the town of Newcastle as associated with the Coal; and beyond a doubt many of the present visitors to this cradle and centre of the coal-trade will have made their journey hither with the expectation of not only hearing communications on various branches of geological science, but more especially of adding something to their knowledge of the carboniferous strata.

We are to be favoured with several papers dealing with different portions of the subject, and I am led to think that, with a view to their scope being fully appreciated, as well as for other reasons which I propose to set before you, it may be advisable that I should invite your attention to the state of our knowledge of the occurrence and history of the coal-measures generally, whilst I refer mainly to the phenomena which characterize that most valuable region in which we are assembled.

In the short time which I will allow my Address to subtract from the hours which we require for the reading and discussion of the numerous papers already sent in, I shall only attempt as it were an overture, giving a general outline of the carboniferous plot, and introducing a few notes to illustrate those passages which are most likely, in our successive acts, to demand attention and concentrate our interest.

The Carboniferous System is commonly divided, for convenience sake, and in accordance with the structure of most European coal-fields, into three principal divisions, viz. the Carboniferous Limestone, the Millstone Grit, and the Coal Measures. I need here say nothing of the Devonian or Old Red Sandstone system, or of the still older rocks which, in the absence of the Devonian, form the foundation of that great division of the geological scale with which we are engaged. The

Carboniferous or Mountain Limestone (the oldest group of strata for our consideration) might be hastily passed over, but for its presenting in this northern district a transitional type between Scotland and the south of England no less important in its commercial aspect than interesting to the geologist in the various inquiries which it suggests. Turn to the Mendips, to Wales, or to Derbyshire, and we find the Carboniferous Limestone constituted almost exclusively of actual limestone-strata, amounting to from 300 or 400 to above 1500 feet in vertical thickness, and never exhibiting other than the smallest traces of beds of coal. But in Yorkshire a change sets in: the carboniferous action, if I may so term it, applies the thin end of the wedge, and small seams of coal, of but little value, are intercalated among the beds of limestone, and are associated with a large proportion of shale and sandstone, stratified with a remarkable regularity. Advancing northward, these seams increase in number and importance. Throughout the great moorland region which culminates in Cross Fell, the same strata, rising from far beneath our feet as we stand here on the lower Tyne, emerge to the daylight, and compose the substance of the Pennine chain which, with its lofty and heather-purpled undulations, forms the broad dividing ridge of northern England.

In the region of Weardale and Aldstone Moor, where in the becks and burns, and in the great escarpment which towers above the valley of Eden, excellent exposures of the strata invite their study, the shales are often very similar to those of the coal-measures, though containing but few vegetable remains: the sandstones and grey beds frequently exhibit stems and fragments of plants familiar to us in the overlying strata, and the coal-seams are *crowcoal* or anthracite, resting on a bed of indurated silicious silt or of clay.

Northward, however, of the great fault which runs nearly parallel to, but south of, the Newcastle and Carlisle Railway, the coal-seams become, and as it appears suddenly, bituminous, and the lower division of the limestone admits more numerous intercalations of shale, sandstone, and coal; and when we follow it to the upper district of the North Tyne, and beyond the river Coquet, the violent folding and contortion to which the strata have been subjected bring into view new basins or fields of coal. The true position of these is far beneath our ordinary measures, and has been recognized as such in Scotland, where they attain a vast importance. In the Berwick district, which has been minutely described by Mr. Boyd, it would appear that about 400 fathoms of carboniferous-limestone measures have been detailed below the Whin Sill or basaltic bed, and about 100 fathoms above it, including in all twelve seams of coal of from two to four feet each. Certain of these, the Scremerston seams, appear to be remarkable in having a limestone roof. For the details of another of these basins of the limestone-coals I may refer you to an excellent paper by my indefatigable friend Mr. Nicholas Wood, published, as is Mr. Boyd's paper, in the 'Transactions of the Institute of Mining Engineers.'

Let us pass from the upper beds of the limestone to the next overlying group of deposits. The millstone-grit or Farewell Rock, as it is sometimes called by colliers, embraces a series of strata unproductive in coal, and in which conglomerates and coarse and silicious grits often preponderate. With this rugged crown many of the fell-tops are capped; but before it bends downwards to pass under the first strata of the coal-measures, we may frequently find with it strata of shale, and sandstone, and fire-clay, roughly similar to those of the true measures, yet presenting to a practised eye peculiarities of structure and colour.

As we descend eastward from the higher ground of the moorlands, on the edge of which the first or Brockwell seam of coal is traced, and as we find new and higher seams constantly succeeding, and the strata inclined regularly towards the sea, we pass into the midst of that tract which, extending from the river Coquet on the north to near the Tees on the south, for 50 miles in length, forms the great northern coal-field. The greatest thickness attained by this formation is probably not more than 2000 feet. But it would be vain for me, within a limited time, to offer you details of the strata—a subject which has been amply treated by Mr. Buddle, Mr. Wood, Mr. T. Y. Hall, Mr. Greenwell, and others. Let it suffice to say that in this thickness there exist, associated with shales of many varieties and with fine-grained sandstones, some 57 beds of coal, from an inch thick upwards, comprising in all 75 feet of coal; whilst those which are considered the workable seams

are twelve in number, giving an aggregate of about 50 feet of coal. The most famous of these seams, from above downwards, are the High Main, the Yard Coal, the Bensham, Five Quarter, Low Main, Lower Five Quarter, Ruler or Hutton Seam, the Townley or Beaumont, the Busty Bank, Three Quarters, and the Brockwell.

On the east the coal-measures are overlain, in a line running from South Shields past Houghton-le-Spring to near Bishops Auckland, by the Permian Series, represented by the Magnesian Limestone and the Lower Red Sand—that unequal and water-bearing bed which forms the great obstacle to the sinking of shafts to the underlying coals. Prejudice, it is well known, even after the difference of these strata from the mountain limestone was proved, long contended that the coal could not be found continuous beneath the magnesian limestone; and it is still asserted that the seams have proved inferior when they pass beneath it, as shown especially by the failure in certain tracts of the Five Quarter and Hutton Seams. But no sufficient reason is apparent why such deterioration is not rather to be ascribed to that variation in quality which all seams are found to undergo when followed over a large area, than to the evil influence of an unconformable upper formation. The variation here alluded to exercises an important bearing on the commercial relations of different parts of the field; and whilst the best "household coal," bright, giving a black cinder, and free from ash, extends from the Tyne to the Wear, and from the last river to Castle Eden, and occupies another area about Bishops Auckland, the steam coal, more dense, and yielding a white ash, characterizes the district beginning some five miles north of the Tyne; and the tender coal, best suited for coking, is largely worked all along the line of the western outcrops, from Ryton down to the outskirts of Raby Park.

As regards the physical agencies which have impressed its present form on this great coal-field, I would remark that they appear to have acted with upheaval in a north and south direction, as evinced by the regular strike over a great length of country. This was accompanied or followed by transverse fractures resulting in several very pronounced lines of fault. Two of these, running respectively east-north-east and east-south-east, are the whin or basaltic dykes named the Hett and the Cockfield dykes. Of the others the most noticeable is the great fault called the Ninety-fathom Dyke, which, starting from the coast near Cullercoats, where it displaces the strata to that amount, ranges past Gosforth to Blaydon, and then entering on the more hilly ground, may be traced westward to the New Red Sandstone of the neighbourhood of Carlisle. Along this western part of its course its throw is so great as to inlay, as it were, on its north side, in the midst of the limestone district, a long strip of the coal-measures of the Newcastle field, and thus to give rise to the collieries of Stublick, Midgeholm, Tindal Fell, &c.

The coals and other strata of this field have sometimes been compared with those of Belgium; but when we regard the decided east and west direction of the troughing and folding, and the vast number of thin seams which are so noticeable in the latter, we may conclude more properly that it is in the peculiar and often similarly circumstanced coal-field of Somersetshire that we have to seek for the direct continuation of the field of the Low Countries.

Let us now cast a brief glance on the theoretical side of the subject. Upon the mode of origination of the limestone, the shale, and the grit or "post," little difference of opinion is now entertained. That the coal itself has been formed purely from vegetable matter can no longer be questioned. The view originally propounded by De Luc, that the vegetation now composing our coal-seams grew on the soil which actually forms the bed or "thill" of the seam, has met with very general acceptance, notwithstanding the difficulty of adopting it in certain exceptional cases. That this dense mass of vegetation flourished and swelled over an area frequently subjected to depression beneath the neighbouring water admits of but little doubt. Such an hypothesis serves to explain not only the equable covering of the coals with their roofs of muddy or sandy matter, afterwards consolidated into shale and grit, and exhibiting to our gaze the remains of mollusca and fishes which tenanted the waters of those depressions, but indicates also the mode in which certain seams have been divided by a parting almost imperceptible in one place, but amounting to many feet in another. The well-known Busty Bank seam

of the western district, some 5 feet thick, including a clay band of 11 inches, is thus divided, in a distance of two or three miles, by the increase of the parting to 18 feet, into the Stone Coal and the Five Quarter at Garesfield Colliery. A still more remarkable instance is the Tow Law seam, at the works so called, 6 feet 3 inches thick, which, by the increase of a parting as it goes eastward, exhibits at Bowden Close Colliery, only three miles away, two seams divided by no less than 16 fathoms of ground, in which beds of sandstone or "post" and even thin seams of coal have been intercalated *.

Such partings, when composed of shale, are often one mass of *Stigmaria*-impressions, and thus form no exception to the generally important part which that fossil plays as the root of the chief plant of the coal. But when the partings consist of fine-grained clean sandstone showing no trace of rootlets, I confess that the appearance of bright solid coal resting upon them seems to me to demand some other explanation. Instances of this kind observed in South Staffordshire and in the Whitehaven Collieries induce me to think that the material must in some cases have been introduced between the laminæ, and sometimes even diagonally athwart them, subsequently to the solidification of the coaly matter.

But there are several curious phenomena as to which a doubt frequently arises, whether they are due to action during or after the formation of the coal; and deductions of no small practical importance sometimes depend on the question. Thus Mr. Hurst † has given a very exact account of irregularities, especially *swellies*, or narrow depressions in the Low Main coal, which appear to have been formed prior to the deposition of the upper seams. On the other hand, Mr. Marcus Scott has excellently described ‡ a broad valley of denudation which was eroded in the coals of the Shropshire field, and filled in with higher unproductive measures.

Again, with some of the slips and faults, or "troubles," we may occasionally observe both coal and ironstone beds so to change in approaching them, or to vary so much on opposite sides of them, that whilst in some few cases we may be led to suspect their contemporaneity with the beds themselves, there are many more which we cannot explain without supposing that the coal must at the time of the disruption have been moulded and squeezed in an almost plastic condition.

In the determination of the plants of the coal much has been done; and the Newcastle names of Hutton and Witham have gained deserved honours in the cause. But a great deal remains to be accomplished by microscopic inquiry, and by the observation in the pits themselves of the plants which accompany particular seams. Göppert tells us, of certain coals of Rhine-Prussia and Silesia, that different seams are distinctly formed of different plants,—sometimes *Sigillaria* and *Lepidodendron*, at others Coniferæ, and in many *Stigmaria* being chiefly prominent. May we not by degrees connect the peculiar and perhaps varying character of seams with the special plants of which they are formed? and may we not thus advance to a much clearer perception of the true character of those wondrous primeval forests?

And here I would remind you, that whilst some of our guides in coal geology incline to the opinion of a marine origin for their plants, thus bringing them into natural contact with the fishes and the probably marine shells often found in the shales, others insist on a terrestrial vegetation, and a third party on that of lagoons or sea-swamps and bogs. The last few years have given some weighty arguments to those who insist on a land-forest, however near to the water-level it may have been. We but recently know that among those giant stems of *Sigillaria* the busy hum of flying insects and the merry chirp of the cricket were heard, that scorpions curled their ominous tails, that land-shells crept slimily along, and that several genera and many species of reptiles either pursued their prey along the ground or climbed the trees whose hollow trunks have formed the casket to contain their remains. Here then is a goodly population to vivify the scene which only a few years ago was held to be almost wanting in all but vegetable life; and when we

* This remarkable instance has been described to me by the veteran and accomplished iron-master, Mr. C. Attwood.

† Transactions of the Institute of Mining Engineers, 1860.

‡ Quart. Journ. Geol. Soc. of London.

consider the accidents which have, amid the great decomposition of organic matter, preserved to us those remains, generally enclosed in ironstone nodules, we must feel confident that coming years will have many an additional fact to disclose.

Of the whole range of the carboniferous formation, perhaps the most interesting in several respects is the lower division. Many years ago Professor Phillips described the peculiar group of unquestionably marine shells occurring in the roof of the Halifax coals; and my friend Mr. Binney has traced throughout the length of Lancashire several seams which are thus characterized, and which lie invariably below the thick seams of the main coal-field. I have been greatly interested in hunting up the same group—the well-known *Aviculo-pecten papyraceus*, *Goniatites Listeri*, *Orthoceras*, and *Lingula*—in Derbyshire, in North Staffordshire, and in North Wales. Again, they occur very similarly in South Wales, at Merthyr and Nantyglo, and further west in the Kilkenny coal-field. I have devoted at intervals several days to the search for them along the outcrop of the Durham district, but hitherto unsuccessfully; and whilst their occurrence lends great force to the probability of the original unity and the subterranean connexion of most of our coal-fields, their apparent absence in the Durham and Cumberland lower coals appears to indicate a peculiar difference in the conditions of deposition. The identification of distant seams, and of low as compared with high measures, appeared on this evidence very feasible; but Mr. Hull has not long since shown that caution is still needed, by announcing the occurrence of the same group of fossils in the roof of what appears to be a higher seam in Lancashire.

It is, I believe, only from the fossil side of the question that we can obtain a proper view of the position, with respect to true coal, of the cannel, the Torbane-hill or Boghead mineral, and bituminous shales. These various substances, whose affinities have formed the subject of such serious litigation, may occur interstratified with, and under circumstances analogous to, the seams which we all, without exception, recognize as coal; but when we come to examine their fossil character, the evidence thus obtained seems to me to point to quite a different mode of formation. On the one hand, observe in the coal the comparatively uninjured cellular tissue of the vegetable mass, and the remarkable freedom from simultaneously deposited foreign matter; on the other hand, take the series beginning with the best cannels, and passing through the various grades of the carbonaceous and bituminous shales, the "parrots" and the "rattlers" and the "black bats," and you find that in these latter an unbroken transition links the one to the other. In all of them the mashed and comminuted state of the carbonaceous element, and the frequent presence of fish-teeth, scales, and coprolites, and occasionally of mollusca, indicate conditions different enough to warrant a geological, let alone a technical separation.

If the shales which form the roof of a bed of coal be carefully examined, it will often be found that successive layers, from half an inch to several inches in thickness, are loaded with distinct kinds of remains, whether animal or vegetable. When they are of that homogeneous, fine-grained, and tenacious quality which constitutes what the colliers term a "good roof," the surface of the coal-seam appears to have been evenly and quietly covered with sediment; when the capping is of sandstone or even of some of the rougher varieties of shale, it may sometimes be seen that the coal has been eroded prior to its being covered up, and occasionally, as in the fine open exhibition of the Brockwell seam at Hownes Gill, near Shotley Bridge, irregular fragments of the coal lie strewed along the top of it, forming a coaly breccia. The under part of the shale or "bind" in actual contact with the coal is, with certain seams and in certain districts, a matted layer of large flattened stems of *Sigillaria*, *Lepidodendron*, &c., intermingled with fronds of ferns, whilst at a few inches higher we reach a band consisting exclusively of the flag-like leaves of *Poacites*, or a bed containing fish-remains and the *Unio*-like shells which recent researches have divided into several genera. In other cases, as notably in the "Bottom Hard" coal of Shipley in Derbyshire, the immediate roof exhibits millions of a small brown "*Unio*"; and as you walk in the workings, you look up at the bottom of a "mussel-bed" where whole generations of the mollusk appear to have lived and died. Time would fail me were I to attempt to specify

instances, but it is important to suggest to you that this is a class of phenomena especially calling for the observation of local workers, and one which, I venture to add, would relieve the monotony of mere business underground visits with an interest of a wider and a higher character.

It is well known that the ironstone bands of the coal-measures are among the most prolific sources of the objects of these studies, and I must, in conclusion, refer to the very interesting lists and parallels of fossils prepared by Mr. Salter for the two last numbers of the "Iron Ores of Great Britain," in the 'Memoirs of the Geological Survey.' The rich stores obtained by zealous collectors in South Wales, and those yielded by the productive strata of the Potteries coal-field, have been formed under his careful hands into a very valuable foundation, upon which I trust that we may soon see in course of erection a systematic and comparative natural history of the British coal-fields.

On the Metamorphic Origin of the Porphyritic Rocks of Charnwood Forest. By Professor D. T. Ansted, *F.R.S.*

The proposition of the author was that the so-called igneous rocks of the district were a series of metamorphosed sedimentary deposits, probably comparable with those of North Wales. The slates of Charnwood, with their contained rolled pebbles and faint traces of life-remains, are known to alternate with rocks having the appearance of syenite; but he regarded the whole as of sedimentary origin.

On a Deposit of Sulphur in Corfu. By Professor D. T. Ansted, *F.R.S.*

Among certain gypseous marls and extensive deposits of gypsum on the northern side of the transverse limestone-axis of the island of Corfu many thin seams of native sulphur, almost chemically pure, are known to occur. Of these one series, from $\frac{1}{4}$ of an inch to $1\frac{1}{2}$ inch in thickness, was examined by the author; and he was informed of another lower series of thicker beds. The surface of the sulphur in some cases presented a somewhat stellate appearance not unlike that common in wavellite. In the village of Spagus, near the deposits, the houses and walls are built of the gypseous rock, with occasional sulphur bands. Springs of water, smelling strongly of sulphuretted hydrogen gas, exist in the neighbourhood. A large quantity of sulphur had been removed for local use.

The sulphur has not been found on the south side of the principal mountain-axis of Corfu, though it recurs in some of the other Ionian Islands, especially in Cephalonia. All the islands are subject to frequent earthquake-disturbances, but these are by no means synchronous—the earthquakes that affect the different islands not being in any way identifiable. Thus, within the author's experience, earthquakes had occurred on one day in Santa Maura and on the same day in Cephalonia at a very short distance, but by no means at or near the same hour. The author connected the sulphur phenomena with the volcanic operations going on at a moderate depth beneath the surface.

On some Facts observed in Weardale. By C. Attwood.

On the Pennine Fault in connexion with the Volcanic Rocks at the foot of Crossfell; and with the Tyndale Fault, called "The Ninety-fathom Dyke." By W. Bainbridge, *F.G.S.*

After a brief description of the great escarpment of the Mountain Limestone system, underlaid at the base by the Old Red Sandstone conglomerate, the effects of the fault are traced in the line of "edge beds" from Ravenstonedale to Tindale Fell, which consist, in different places, of the Great Scar Limestone, the Old Red Sandstone, the Silurian Slates, the Coniston Grit and Limestone, and northwards from Hartside Fell of the higher beds of the Mountain Limestone system.

The band of volcanic rocks, about two miles in its greatest width, 1400 feet in height from the base in Murton Pike (the highest of the Pikes), and about 20 miles in length, occurs between the New Red Sandstone of the Vale of Eden and the

mountain chain, and is diversified by many most picturesque forms as well as many shapeless mounds. Crossfell and the adjoining region form the highest parts of the Pennine chain, and, opposite the greatest elevation of the volcanic rocks on the other side of the chain, ten miles distant, the basaltic bed called the "Whin sill" attains its greatest thickness (40 fathoms) and its greatest intensity of chemical action. The Red Sandstone is washed up into all the irregular spaces of the hills, both limestone and volcanic, thus proving its deposition after the elevation of the hills was accomplished.

The volcanic band is described in detail from near Brough, in Westmoreland, to Hartside Fell. Murton Pike is conical, and abuts against a lofty convex cliff of limestone, resting also partly on its ledge above. Dufton Pike, a striking pyramid of 1575 feet of absolute height, and about 1000 feet from the base, with a slope of from 28° to 33°, is completely isolated. The rock is apparently cut off on the north by the great Crossgill vein traversing the Alston Moor district east and west for many miles, and ending at the escarpment; and the southern limit is very near the great independent dislocations in Lunedale and Stainmoor, which produce so much confusion in the neighbourhood of Brough, and even change the southward course of the Pennine Fault.

Between the Eden New Red Sandstone and the western side of the volcanic band there is a narrow line, often faintly traced, of limestone and shale beds, dipping rapidly under the Red Sandstone, which have been broken off from the chain by the fault. The limestone is light blue, dark blue, brown, and almost white, and often crystalline. The greenstone passes into slate, grey or whitish. The former is a dull dark substance, varying in hardness, liable to decomposition, but often very compact. Analysis of specimens from Dufton Pike :—

Greenstone.	
Silica	75
Iron and alumina	13
Lime	5
Magnesia	trace
Loss—heating	6·50
	99·50

Slate.	
Silica	70·50
Iron and alumina	24
Lime	trace
Magnesia	trace
Loss	1·50
Alkalies and matters not found by difference	4
	100·00

On the west side of Dufton Pike occur beds of granite, apparently in round or oval deposits, and like that of Shap Fell. Smooth boulders of this granite, of basalt and of quartz rock, are dispersed on the flanks of the chain and on the volcanic hills. There are also veins or dikes across the line of volcanic action, containing quartz, felspar, and talc. There are signs of parallelism in the process of eruption; but there is no appearance of craters. The three large Pikes are striking examples of regular forms produced by processes of degradation.

The ninety-fathom Slip-Dike, or Tynedale Fault, is then traced from the sea to Hartley Burn, where the narrow line of the Newcastle Coal-field, thrown down to the north by the fault, disappears. A large basaltic dike accompanies the fault for many miles across the rivers Allen and South Tyne, at 200 yards' distance on the south. Another basaltic dike passes on the north side of the fault from Chollerford, crosses the Tyne thrice, and is supposed to enter the Hartley Burn district considerably north of the coal-field there. This coal-field has been worked to the extreme west end, where it appears to be cut off by a slip-dike running N.N.W. and afterwards W.N.W., and much broken and very irregular. It appears to rise to the W. and N.W., and the coal-beds dip for about 40 yards to the north. This outcrop of the Newcastle Coal-field is only three-quarters of a mile distant from that of Tindale Fell, in the mountain-limestone chain. It seems, therefore, probable that the former coal-field is simply terminated by its junction with the Pennine chain. A slip-dike, seen near Blenkinsopp, may be the same that appears to cut off the coal, and afterwards to pass by the base of Halton Lee Fell, through Tindale Fell, into Geltsdale. The vertical beds appear faintly, but distinctly, in Blackburn in this direction. The slip-dike that throws down the Tindale Fell coal to Talkin Fell, for 40 fathoms, runs W.N.W., and appears to be confined

within the mountain-limestone system. A basaltic bed, that chars the coal, underlies the seams at Hartley Burn and Midgeholme.

In considering the connexion between the two great faults, we are led to the question of geological age. If the faults had taken place at the same time, the age of both might have been fixed during the Permian period, viz. after the deposition of the magnesian limestone, and before that of the New Red Sandstone. For, at one end, there is the overthrow of the magnesian limestone at Cullercoats; and at the other, the almost vertical disturbance of the magnesian conglomerates at Brough, and the unconformable deposition of the Eden New Red Sandstone against the mountain limestone and the igneous rock. The deposition of New Red Sandstone upon the small Ingleton Coal-field is also noticed. As this sandstone is wanting at the mouth of the Tyne, and as the Tynedale Fault is not observed to penetrate through the chain into the Eden New Red Sandstone, there is negative evidence to the effect that the fault *might* have occurred after the Permian system was complete. On the other hand, the two faults might apparently have occurred, as one physical event, or as nearly contemporaneous, *after* the deposition of the coal-measures, which are dislocated by the Tynedale Fault, and *before* that of the New Red Sandstone. In that case, the coal ought still to have existed on some parts of the mountain chain. But there is not a vestige of coal on that chain throughout its entire length, from the base of the Cheviot to its southern limit. The elevation, therefore, of that chain, and the crisis of the Pennine Fault, must have happened either before the deposition of the coal, or after the chain had been denuded of coal already deposited. But the Tynedale Fault is supposed to throw down the coal 1200 to 1800 feet at its intersection of the chain, not far from its axis. At any rate, it is thrown down there from a considerable height. It can hardly, therefore, be doubted that the coal once existed throughout the chain upon the millstone-grit, and was washed off during the partial submergence of the chain. In that case, it would follow that the Tynedale Fault, occurring *after* the deposition of the magnesian limestone, and before that of the New Red Sandstone, is *older* than the Pennine Fault, and that the latter fault, with all its volcanic consequences, might have occurred within the same geological epochs, but after the effects produced by the Tynedale Fault. This denudation of coal would of course imply an intermediate subsidence of the mountain-limestone system, during which the coal of the chain, both north and south of its depression and burial along the line of the Tynedale Fault, would be washed away. When the chain again began to rise after the denudation of the coal, the present abrupt termination of Tindale Fell, towards the north, and its great height above the plain at Hartley Burn might be occasioned by the unequal elevation of the surface in the neighbourhood of the Tynedale Fault, on a different axis which prevails, north of that fault, to the German Ocean.

There appears to be direct evidence in the disturbed magnesian conglomerates, near Brough, that the Pennine Fault, which followed the final elevation of the chain, may have occurred after the dislocation of the magnesian limestone at Cullercoats.

Professor Phillips, while admitting the objection arising from the above disturbance, and the great difficulty of the problem, inclines to the conclusion that the Pennine and Craven Faults preceded the magnesian-limestone epoch, and that the Tynedale Fault was of somewhat later date. He finds also a close analogy between the small Ingleton Coal-field and that of Hartley Burn. But there is this difference, that, though apparently thrown from an almost equal height, the Hartley Burn coal is not absolutely detached, like that of Ingleton, from other large coal tracts of the same kind, but is connected directly and continuously with the Newcastle Coal-field; that the seams do not, as at Ingleton, thin off to nothing, without any apparent cause, but are quite as thick there as at any other place along the line, and are cut off by dislocations of great extent. It is possible that the Ingleton coal may, from causes operating on a limited tract, have escaped destruction, and been afterwards thrown down by the Craven Fault. The existence, therefore, of this line of coal seems to show that the Tynedale Fault must have preceded the Pennine Fault. As a general rule in this district, the east and west veins are older than the north and south veins; and the same rule may prevail with respect

to large fractures or faults. This priority appears to be most reconcileable with what is now to be seen. If the Pennine Fault had been first, it might naturally have been expected to have extended in a straight line northward towards Eskdale; but it does not extend beyond the line of the Tynedale Fault; and, on the river Irthing, the beds are remarkably regular, in a dip S.S.W., and without any trace of faults, running north and south. Again, the Tynedale Fault might perhaps have been expected to penetrate the Pennine chain at this point of supposed depression. On the other hand, the previous existence of the Tynedale Fault, as a vast cross fracture, might be expected not only to influence the subsequent elevation of the chain, but also to cause the divergence of the "edge beds" of the Pennine Fault towards the N.E., and, in part, to deprive that fault of its usual power. Both these effects appear to be still visible; yet, after all that has been said, there is abundant scope for further observation and reasoning.

On the Physical Condition of the Earth in the Earlier Epochs of its History. By the Rev. James Brodie, *Monimail.*

The author maintained that the condition of the earth in the earlier epochs of its history may have been the effect, not of internal, but of external heat, in the following propositions:—1. The greater heat of the temperate and polar regions, in the earlier eras, cannot be accounted for on the supposition that the distribution of land and water was different from that which now exists. 2. The change which seems to have been produced on the metamorphic rocks was not caused by heat from within acting upon them while they were covered with a mass of superincumbent strata. 3. We have no conclusive evidence that the temperature of the central part of the globe is higher than that of the surface. 4. There is no evidence that the great mass of the earth has ever been in a fluid state. 5. All the phenomena hitherto observed may be satisfactorily accounted for on the supposition that the earth was at some former time exposed to great external heat.

The general inference which he deduced from his observations was that, in all speculations in regard to the physical condition of the earth in former epochs, it should ever be kept in mind that an increase of temperature implies an increase of atmospheric pressure, with all the effects on chemical combinations and animal and vegetable development which such an increase would produce.

On Artificially produced Quartzites. By Alexander Bryson.

The author gave in detail the results of experiments he had lately made with certain siliceous minerals. A brown crystal of Cairngorm quartz, exposed to the heat of a brick-kiln for six days, lost its carbon and came out white, having, nevertheless, increased in specific gravity from 2·6458 to 2·6571. An amethyst treated in a like manner became changed into opal; red granite of Peterhead so exposed turned white, but black basalts came out red, and the colour of Arran pitchstones was found to be permanent. He also exhibited a slice of silicified monocotyledonous wood with annular layers, in which the crystals of silica were observed to have broken up the tissues of the plant. Referring to the question of fluid in siliceous rocks, he believed that no cavity had been filled at a higher temperature than 94°.

On the Causes of Earthquakes and Volcanic Eruptions. By J. Alexander Davies.

The theory of the author was that these phenomena, generally preceded by atmospheric alterations unusual in degree, were also connected with them, and, indeed, caused by them.

On Two New Coal-plants from Nova Scotia. By Dr. Dawson.

One of the plants (*L. Acadianus*) belonged to the genus *Lepidophloios* of Sternberg; the other was an example of a type of *Lepidodendron*, very characteristic, in Nova Scotia, of the Lower Coal-measures associated with the Lower Carboniferous Limestone. The author concluded that the original species of Sternberg (*L. Lari-*

cinum) was founded on the fragment of the bark of an old trunk, having the leaf-bases flattened, and hence described as scales. It was evidently, in short, closely allied to the specimen described. The genus *Ulodendron* was, he thought, identical with *Lepidophloios*, but apparently founded on specimens having the leaf-bases preserved, with the cone scars, but wanting vascular scars; but he was in doubt as to the claims of the name *Ulodendron* on the ground of priority. It appeared to him that the generic names *Ulodendron, Lomatophloios, Leptoxylum, Pachyphlœus*, and *Bothrodendron* should be abolished in favour of *Lepidophloios*, unless indeed it should appear that any of these names had priority in date. The second plant described was the *Lepidodendron corrugatum*, which was one of the most abundant in the Lower Coal-measures of Nova Scotia and New Brunswick. The species was remarkable for its variability, and also for the dissimilar appearances of old stems and branches occasioned by the separation of the areoles in the growth of the bark, instead of the areoles themselves increasing in size, as in some other *Lepidodendra*.

On the Relations of the Cumberland Coal-field to the Red Sandstone. By W. Matthias Dunn, *Government Inspector of Coal-mines.*

The author's practical investigations in the collieries of Ellenborough, Aspatria, and Crossby led him to consider that the main coal-field of the district yet remained untouched, as it had been downcast by faults beneath the Red Sandstone rock, which he is inclined to regard as the superior stratum of the Carboniferous system. Quoting several authorities in support of his opinion that the bottom of the basin would be found at and around Silloth Harbour, he pointed out the importance of determining the question, and described the trial sinkings now going on near Wetherall and at the Aspatria Colliery.

On a Salamander in the Rothliegendes. By Dr. Geinitz *of Dresden.*

It was found some years ago in a slab of grey-marl slate, at Selberg, near Braunau, belonging to the lower Rothliegende, not to the Kupferschiefer. Dr. Geinitz had proved the relation of this fossil with the living *Siren lacertina*, L., of North Carolina, so that he was persuaded he had in the fossil an old and gigantic *Siren* (a Salamander), whose dimensions exceeded those of the living species about ten times. There were preserved three and a half vertebræ, with a part of the skin; and the name proposed was *Palæosiren Beinerti*, Gein.

On the Alluvial Accumulation in the Valley of the Somme and Ouse. By R. A. C. Godwin-Austen, *F.R.S.*

The object of the paper was to show that these two river-valleys belonged to areas over which the geological changes had differed so greatly that, at present, comparisons could not be made; that the materials of the gravel-beds of the Ouse had, like those of all the rivers of the east of England, been derived from the "boulder-formation;" and that the state of the animal-remains indicated that they belonged to the fauna of the period antecedent to the boulder-clay; consequently that, should it be proved that flint implements were to be met with in the Bedford gravel-beds, it would not prove that the *Elephas primigenius* and its associates were contemporaneous with man. The valley of the Somme was shown to belong to an area which lay beyond the "boulder-formation"—that the series of alluvial beds differed greatly in respect of the physical conditions under which they had originated, yet that they indicated a definite order of succession, and implied a vast lapse of past time; in each of these flint implements have been said to have been found. The only evidence on this point which the author considers to be reliable is that with respect to the Champ de Mars, near Abbeville, where the beds belonged to the most recent portion of the alluvial series of the Somme, in the "subaërial" accumulations. The author further showed that there is no sufficient evidence of a post-glacial elephantine period, as also that the Somme valley could never have been the line of drainage of a vast river, but that the phenomena of river alluvia at great elevations are to be accounted for by physical changes of definite date.

On the Reptiliferous and Footprint Sandstones of the North-east of Scotland. By Professor HARKNESS, *F.R.S.*

The author, after having carefully examined all the localities in the district around Elgin where rocks are exposed, has been enabled to arrive at a series of sections which place the reptiliferous sandstones of this neighbourhood in their proper position.

The arrangement of the strata in this part of Scotland was made out generally by Sir Roderick Murchison and Prof. Sedgwick about thirty-five years ago, and subsequently Sir Roderick Murchison has added considerably to the details of the geology of this area. The rocks in this part of Scotland were all regarded as belonging to the Old Red Sandstone group until, a few years ago, the remains of a Crocodile (*Stagonolepis*) were discovered in the higher portion of the series. This led palæontologists to look upon the reptiliferous sandstones of Elgin as appertaining to the Triassic formation; but, from the sequence of the strata and their mineral nature, some geologists have still regarded these rocks as upper members of the Old Red series. As no distinct sections had been made out of the sequence of the strata, the evidence of conformability between the several strata was not perfectly satisfactory. The author has, from his observations, now obtained a series of sections from the lower beds of the Old Red, which, in this district, repose upon the metamorphic rocks, to the deposits which overlie the reptiliferous sandstones. These sections exhibit the following sequence of rocks:—Base of the Old Red (which here does not manifest the lowest nor even the middle members of the group), a mass of purple conglomerate, succeeded by purplish sandstones (Scat Crag beds) with remains of *Bothriolepis* and *Holoptychius*, upon which repose grey sandstones with pebble-beds containing the same fossils. These latter pass upwards into yellow sandstones (Bishop's Mill beds) containing *Holoptychius* and *Glyptopomus*, have pebble-beds above them, and upon these latter the reptiliferous sandstones repose, being succeeded by limestone (cornstone). The whole of the strata have *a perfect conformity*, and the agreement in the conformity and the sequence of the strata can be seen in several spots in the district around Elgin.

The author next described a continuous section seen along the Ross-shire coast, from the Nigg to Tarbetness. In this section the whole of the Old Red Sandstone, from its lower members to its upper beds, is seen continuously, the sequence and conformity of the deposits being perfect. From the upper beds of this section the Rev. Messrs. Campbell and Joass have obtained footprints, some of which are identical with the Ichnolites from the reptiliferous sandstones of the Elgin country, and the upper members of the Old Red Sandstones here have a great affinity in nature and sequence to their representatives on the southern side of the Moray Firth. From this section in Ross-shire, and from the sections which can be obtained in Morayshire, the author has now no doubt that reptile life, in the form of Crocodiles and in other forms, existed during the deposition of the strata which make up the higher members of the Old Red Sandstone in this part of Scotland.

On the Fossils of the Skiddaw Slates. By Professor HARKNESS, *F.R.S.*

The Skiddaw slates, lying above the Lingula-flags, had at one time been regarded as Azoic. They were first brought within the series of rocks producing life-remains by Professor M'Coy, who described two Graptolites and sea-plants (*Chondrites*) discovered in them. Investigations lately made by the author in the neighbourhood of Keswick had removed them in palæontological character very far above their supposed position. He had obtained the remains of a shrimp-like Crustacean, allied to *Ceratiocaris*, upon which Mr. Salter had founded a new genus, *Caryocaris*, and a shell of *Discina*. The family of Graptolites, regarded as typical of the age, had been increased by his investigations, representatives of seven genera having been obtained, four of which were confined to this group of rock strata. The forms discovered belonged to the genera *Dendrograpsis, Phyllograptus, Tetragrapsus, Dichograpsus, Didymograpsus, Diplograpsus,* and the better-known Graptolites. In conclusion, Professor Harkness alluded to the fact that the forms of Graptolites which occur the earliest in time are of the most complicated design, thus affording no support to the progression-theory.

On the Hornblendic Greenstones, and their relations to the Metamorphic and Silurian Rocks of the County of Tyrone. By Professor HARKNESS, *F.R.S.*

The eastern portion of the county of Tyrone is made up of rocks, in part consisting of hornblendic greenstones, flanked on the north by metamorphic masses, and on the south by the Silurian beds, which have been described by General Portlock as being well exhibited near Pomeroy. The metamorphic rocks on the north and the fossiliferous Silurians on the south dip in opposite directions, and the intervening hornblendic greenstones seem to form the axis of the elevation of the altered and unaltered rocks. These hornblendic greenstones are, in some localities, penetrated by granite. The author, from his observations in this part of Ireland, is induced to conclude that the metamorphic rocks in the north of Ireland, and also those of the Highlands of Scotland, have been elevated, flexured, and contorted at a period antecedent to the time when the granitiform masses were thrust into the metamorphic strata, and he is disposed, from the mode in which the granites sometimes exhibit themselves, to regard them as the result of an excess of metamorphic action.

From the mode of occurrence of the metamorphic rocks on the north of the hornblendic greenstone and the unaltered Silurians on the south thereof, he looks upon these rocks as appertaining to the same geological epoch; and judging from the fossils of the unaltered Silurians, these rocks belong to the age of the Caradoc beds, a period to which the bulk of the metamorphic rocks of the north of Ireland and the upper gneiss of the Highlands of Scotland are also referable.

On the Fossil Teeth of a Horse found in the Red Clay at Stockton. By JOHN HOGG, *M.A., F.R.S., &c.*

The author exhibited three fossil molar teeth of the lower jaw of a Horse, and remarked that few occurrences of Mammalia, in a *fossil* state, had been recorded in the adjoining counties of Northumberland and Durham; indeed, only once before the teeth of a Horse had been described.

These specimens were dug up in the Red Clay of the New Red Sandstone to the south of the town of Stockton-on-Tees, and at a depth of 4 or 5 feet.

The author also compared with them three molar teeth of a Horse, which he had found last autumn, with a portion of a human skull, in a field at Norton, where, in local history, it was related that a battle had been fought some centuries ago. It is the *same* field as that noticed by him to the Ethnological Subsection at Swansea, and mentioned in the Report of that Meeting.

He further compared with the fossil teeth the corresponding molar teeth of the lower jaw of a recent Horse. The fossil teeth differed from all the more modern ones by their strength, size, colour, and glazed exterior.

On the Metamorphic Rocks of the Malvern Hills. By HARVEY B. HOLL, *M.D., F.G.S.*

The two most southern hills of the Malvern range consist entirely of bedded rocks, chiefly mica and hornblende schists, and gneissic rocks, having a nearly N. and S. strike. In the next, or Midsummer Hill, some thick-bedded rocks, composed of hornblende and felspar with a variable proportion of quartz and diorite, both coarse- and fine-grained, are interstratified with gneissic rocks and mica schist; the direction of the strike being more to the W. of N. and E. of S. In the next, or Swinyards Hill, the strike is due E. and W.: S. of the summit the rocks are gneissic and schistose, with some diorite and quartzo-felspathic rocks regularly interstratified; but, on its northern declivity, these are succeeded by massive and coarsely crystallized granitoid rocks, in which the mica is sometimes replaced by hornblende and epidote. The direction of bedding, though obscured, is traceable by means of narrow belts of more schistose rock, interposed at intervals, and lying in the plane of the general E. and W. strike. No veins proceed from these highly crystalline masses into the adjacent rocks.

In the Herefordshire Beacon the rocks are again gneissic and schistose in structure, partly micaceous and partly hornblendic, traversed by large quartzo-felspathic veins. These rocks are well exposed along the new pathway leading from the

turnpike-road towards the summit, and better still at the Wind's Point. The strike is here E. of N. and W. of S.

From the Wind's Point to the Wych there is a long succession of alternating gneissic and schistose rocks, with occasionally beds of diorite interstratified. In these gneissic rocks, when hornblende replaces the mica, the alternations of the lighter-coloured bands of felspar and quartz with the darker hornblende give to the rock a finely ribboned appearance. The strike towards the central portions of this ridge, as opposite Malvern Wells, is nearly N. and S.; but near to the Wych it varies on either side of E. and W.

Thus far, with the limited exception of the northern extremity of Swinyards Hill, where the bedding has become obliterated, the hills consist of bedded rocks. But N. of the Wych these schists, &c., have associated with them some granitoid rocks, especially in parts of the Worcestershire Beacon, and in the hill which overlooks Dowles Bench. On the southern side of the North Hill, hornblende occupies the place of the mica, and not unfrequently the two are associated in the same mass. Much of this rock, however, has a very gneissic structure. The bedding is entirely obliterated. It is possible that some portions of these more crystalline rocks may have been erupted, but there is no evidence of this beyond their massive character and the absence of veins running from them into the adjacent dioritic and schistose rocks. The gneissic structure which they frequently exhibit, and the manner of their occurrence when viewed on the large scale, are more in accordance with the supposition of their metamorphic origin. The remaining portions of this northern part of the range are made up of gneissic rocks and diorite. The general direction of the strike is N.W. and S.E.

These rocks have a more highly metamorphosed aspect, are more mixed with diorite, and contain more hornblende than the altered rocks of known Cambrian age, and in this respect they bear much similarity to some of the metamorphic rocks on the N. side of the River St. Lawrence.

Throughout the range these rocks are traversed by numerous quartzo-felspathic and granitic veins. Dikes and intruded masses of trap are frequent, twenty-seven occurring N. of the Wych, and six to the south of it. The veins are posterior to all the rocks except the trap-dikes.

The oldest of the Palæozoic rocks of the district are the Hollybush sandstone and black shales, or Malvern equivalents of the Lingula-flags, or Primordial zone of Barrande. At their base there is a conglomerate of quartz-pebbles and rounded fragments of felspar, derived probably from the crystalline rocks against which they rest. Above these are olive and greenish-coloured sandstones, containing dark and bright green particles, probably of volcanic origin, and others that are flaggy and micaceous; and at the little hamlet of White-leaved Oak they contain a band of limestone about 6 feet in thickness. Besides the characteristic *Trachyderma antiquissima* and a *Scolithus*, these sandstones have yielded a *Lingula* and an *Orthis*.

Above these sandstones are the Black Shales. On the western and north-western slopes of the Key's End Hill these shales completely conceal the sandstones, but in the valley of the White-leaved Oak, and on the western sides of the Raggedstone and Midsummer Hills they have been removed by denudation, whereby the underlying sandstones are exposed. These shales contain some well-known Lingula-flag fossils, besides others that have not yet been described.

These sandstones and shales have interstratified with them many beds of volcanic ash, grits, and lava-flows. Some of these form bosses from the denudation of the softer rocks from around them. At least three of these lava-beds occur in the sandstones, and many more are intercalated with the shales; but the exact number is not ascertained. In composition some are felspathic, others felspatho-augitic with crystals of augite?, while some are highly calcareous, as is the case with the boss nearest Bransill Castle and with those on the E. of Coal Hill. Some of the ash-beds contain cavities which have become filled with carbonate of lime or quartz, which in the weathered portions become dissolved out, and restore to the rock its original cellular structure. That these beds are contemporaneous intercalated deposits, and not erupted, is clearly shown in the section at the north end of Coal Hill, where grit-, ash-, and lava-flows are regularly interbedded with decarbonized shale, and dipping with them to the S.W.

All the remaining members of the Lower Silurian series are absent from the district, and the beds which rest upon the Malvern representatives of the Lingula-flags belong to the Upper Llandovery beds, to which all the other subdivisions of the Upper Silurian and the lower division of the Devonian systems succeed conformably. Towards the southern extremity of the hills, and north of West Malvern, the lower purple sandstones occur; but in all the intervening portion of the chain it is the higher beds only that rest upon the metamorphic rocks, overlapping the lower beds, and showing that the central portions of the chain were less depressed during the deposition of the Llandovery rocks than were the two extremities. That the hills were above the sea-level during this Llandovery period is proved by the fragments of the crystalline rocks which these conglomerates contain, as already shown by Professor Phillips.

The cuttings which were made in the construction of the railway brought to light some important faults on the western side of the Wych, which had been previously overlooked for want of sufficient exposures. Of these, the principal, or Colwall fault, crosses the railway-cutting near the western extremity of the tunnel. The interval between the railway and the hills on the south side of this fault contains all the beds from the Upper Llandovery to the Downton sandstone and lower part of the Old Red Marls inclusive. On the N. side of the fault all these beds are carried to the N.W., the Wenlock limestone as far as the turnpike-road, and the Aymestry limestone to Brock Hill. Between the Wenlock limestone on the N. side of the fault and the Downton limestone on the S. side there is, therefore, an interval in which the Wenlock shale is in contact with the Old Red Marls, and through this space the railway passes. At a little distance from this larger fault, on its northern side, are three smaller faults, and still further to the N. a fourth. This latter crosses the tunnel at the shaft nearest the hills, and the turnpike-road at the turning-off to the lime-quarries, and thence passes down the little valley in the direction of Brock Hill.

Another great fault occurs along the western foot of the Herefordshire Beacon, extending from the Wind's Point to Walm's Well. This fault is caused by the upthrust of the metamorphic rocks through the Upper Silurian beds, which they have carried high up before them, at the same time bringing up the Hollybush sandstones and black shales, which, altered by trap-dikes, from the lower hills on the eastern side of the Beacon. All the Upper Silurian beds thus upraised have been subsequently removed by denudation.

There are also some other faults of minor importance.

As the general result of his researches the author infers—

1. That the metamorphic rocks of the Malverns are certainly as old as the lower part of the Cambrian—probably as old as the Laurentian period *.

2. That they were above the sea-level prior to the deposition of the Primordial zone.

3. That during the deposition of the Primordial zone the range was sinking.

4. That subsequent to this, the range was again elevated, and continued so until after the deposition of the Lower Llandovery rocks.

5. That the Upper Llandovery rocks were deposited during a period of depression, which depression continued until after the deposition of the Lower Devonian series; that portion of the range which is between the Wind's Point and the Worcestershire Beacon being the last to be depressed.

6. That subsequently to the Lower Devonian period the range again became elevated, and continued so during the deposition of the Middle and Upper Devonian beds, the Carboniferous limestone, and the Millstone-grit†.

7. That this was again followed by gradual depression, during which the Coal-measures, the Permian system, the Trias, and Lias were deposited.

8. That the age of the faulting of the Upper Silurian and Devonian strata, on the

* By Laurentian period, it is not intended to imply that they are the exact equivalents in time of the metamorphic rocks on the N. side of the St. Lawrence, but only that they are older than the Cambrian System. The term is here used generically to group all the altered rocks which are of pre-Cambrian age.

† These are all absent from beneath the Coal-measures at Martley on the N., and Dymock on the S., where they rest on the Lower Old Red sandstone.

western side of the hills, was at the close of the Lower Devonian period, and probably dependent on the elevation of the range which took place about that time; but that the age of the great longitudinal fault on the eastern side of the range was subsequent to that of the Lias.

Some Facts relating to the Hydrography of the St. Lawrence and the Great Lakes. By Dr. Hulburt.

The effects of frosts and thaws during the Canadian winters are very remarkable on the rivers, smaller lakes, and bays of the great lakes in the valley of the St. Lawrence. One example was given. In the winter of 1861 the writer very carefully examined those effects upon Burlington Bay, at the head of Lake Ontario. The ice at the time was about 15 inches thick. Frequent thaws occur during the winter, at all of which the ice expands with the rise of temperature. With the return of the cold the ice again contracts, but the part which has been shoved upon the shore remains stationary, and the ice opens or cracks in parts over deep water. During twenty-four hours the ice had expanded 6 feet over a distance of two miles, whilst it remained firm on the south side of the bay, carrying with it about 80 feet of a wharf, which broke at the centre, whilst some 80 feet nearer the shore remained firmly imbedded in the ice, that had not yielded. Similar effects were produced in other places along the same shore. This expansion and contraction of the ice is sure to destroy all those bridges and wharfs built upon piles and light spars in the lakes and rivers which freeze over; for the larger lakes remain open during the winter. The boulders of primitive rocks, which thickly strew the valley of the St. Lawrence, are found on one shore of the smaller lakes and rivers to have been carried by the action of the ice far away from the water; and whilst those boulders often occur so abundantly on one shore as to prevent the traveller landing, he is sure to find the other shore quite free from them.

The Upper Tertiary Fossils at Uddevalla, in Sweden. By J. Gwyn Jeffreys, *F.R.S., F.G.S.*

The enormous heaps of fossil shells and barnacles which compose some of the hillsides near Uddevalla have for a long time attracted the attention of tourists as well as of geologists, and they may be considered one of the wonders of Scandinavia. In 1747 Linné published an account of his West Götha journey, which contains a list and figures of the fossils found by him at Uddevalla, as well as some curious particulars as to the calcination of the shells, the Jättegryter (or "giants' pots"), and various other matters which met his observant eye. He enumerated and briefly described nine species of fossils. Early in the present century the Swedish geologist Hisinger and the French geologist Brongniart severally recorded some important facts as to the height of these beds above the level of the sea, and the occurrence of barnacles *in situ* on the gneiss rock, which underlies them, and is laid bare in certain places. In the 'Philosophical Transactions' for 1835 appeared an admirable essay, by Sir Charles Lyell, "On the proofs of a gradual rising of the land in certain parts of Sweden." His notice of the shell-mounds is full of interest; but the geographical distribution of the marine Invertebrata had not been at that time much studied, and our great geologist stated that at Uddevalla "nearly all, perhaps every one, of the species belonged to the German Ocean." The catalogue of fossils from this locality appended to the paper gives twenty-six species; and it shows the laborious research with which the author collected them (with some assistance) in the space of a single day. Two years afterwards Hisinger published his 'Lethæa Suecica,' and added five species to the list. I am not aware that anything more has been made known on this subject beyond a casual, although highly important, remark by Professor Lovén, in the Transactions of the Royal Academy of Sciences at Stockholm, that all these fossils are of an arctic character; another paper, by the same eminent naturalist, identifying a shell from Behring's Straits (*Piliscus commodus*, Middendorff) as an Uddevalla species; occasional references by Dr. Otto Torell, in his valuable treatise on the mollusk-fauna of Spitzbergen, to some of these fossils; and a geological map,

published last year by Olbers, of the Bohuslän district (within which Uddevalla is situate), accompanied by a short explanatory memoir. Professors Sars and Kjerulf have lately investigated, with their usual ability and care, the fossils of the corresponding formation in the Christiania district. Last year I had an opportunity of visiting the so-called glacial formations both in Sweden and Norway, and of examining several collections of fossils from Uddevalla; and I now offer a list of the latter, in the hope that it may be useful to geologists.

The Uddevalla beds which I observed were at Capellbacken and Lilleherstehagen, lying about an English mile from Uddevalla and from each other. I was struck with the variety of conditions which appears at Capellbacken, and in that place compared with the other. At Capellbacken was the solid rock, with *Balanus Hameri* (now an inhabitant of deep water) still attached to it; close by, a raised beach containing *Littorina litorea*, *Mytilus edulis*, and other littoral shells; and within the distance of a few yards lay a confused and thick mass of other shells, some of which (as *Mya truncata* and *Pholas crispata*) live within tide-marks, while others (as *Pecten islandicus* and species of *Astarte*) frequent deeper water. This assemblage seemed not to be different from the *débris* which would be cast up on a modern arctic beach. Scarcely any of the shells were broken or rubbed. Many specimens of *Mya truncata* and *Saxicava arctica* were perfect, and had the valves united, although the ligaments had disappeared. The *Mya* was not *in situ*, as I afterwards saw it at Tufve, in the island of Hisingen, near Gottenburg. Several of the species which composed the great shell-heap (e. g. *Terebratella spitzbergensis*, *Lepeta rubella*, *Cyclostrema costulatum*, *Mesalia borealis*, and *Velutina undata*) have not been found living south of the Arctic circle; and as most of the other species are also inhabitants of high latitudes, it may be safely inferred that all of them existed in a climate similar to that of North Greenland or Spitzbergen. One exception, however, is so remarkable that I will mention it, although not without considerable distrust. It is that of *Cypræa lurida*, a Mediterranean shell. Mr. Thorburn showed me a specimen which he had found in the shell-heap at Capellbacken: it had the semifossilized aspect of the other shells, and exhibited no trace of the bright gloss which characterizes fresh or recent specimens of this kind of cowry.

The formation consisted of several distinct layers, and apparently represented many epochs and conditions. Some of the strata were probably elevated, and others depressed, at alternate periods and irregular intervals, but by slow degrees. An instance of such a diversified and long-continued movement occurs at Capellbacken. There, within half an English mile of the little town of Uddevalla, is a steep and winding ravine, down which flows a small stream. The banks on each side are formed entirely of shells closely packed together, with but a slight admixture of sand. The lowest stratum rests on a rock of gneiss, and consists of a firm bluish clay, called by Swedish geologists "fucus-lera." Dr. Torell informs me that it contains *Leda* (*Yoldia*) *truncata*. I did not observe any shells or fossil organisms in this bottom layer; but only a small part of it was uncovered, and not being provided with workmen or tools, I could not ascertain its thickness. Over it was a bed of sandy gravel, with rolled stones or pebbles, containing *Mytilus edulis* and a small form of *Saxicava arctica*. This bed was about six inches deep and resembled a raised beach. Judging from the angle at which it dipped, and from the nature of the superincumbent layer, I traced it for about 200 yards further up the hill, where it cropped out or came to the surface. The third or uppermost layer was the compact mass of shells above mentioned, comprising *Mya truncata* (var. *uddevallensis*), an unusually large and solid form of *Saxicava arctica*, *Buccinum grœnlandicum*, *Trophon clathratus* (or *scalariformis*), and various other shells, besides innumerable valves of *Balanus Hameri*, with its operculum and plate of attachment. This great layer was from 20 to 30 feet thick in some places; and its summit is said to be about 200 feet above the sea-level: the Swedish foot differs from ours in being only three-eighths of an inch less. At Lilleherstehagen, which lies about an English mile east of Uddevalla, another extensive deposit is partially exposed. Here the upper layer gives a singular result. Mixed with the universal *Trophon clathratus* (which is a high northern species, and found living only within the Arctic circle) are many shells of rather a southern type. Such are *Ostrea edulis*, *Tapes pullastra*, *Corbula gibba*, and *Aporrhais pes-pelicani*. All these species,

however, have been recorded by Sars as inhabiting the coast of Finmark, although they are also natives of the Mediterranean. According to Dr. Torell a living oyster has never been found in the seas of North Greenland or Spitzbergen. Dr. Malm says that *Isocardia cor* and *Tapes decussata* (usually regarded as southern forms) are fossil in lower deposits at Uddevalla, and that *Mytilus edulis* and *Balanus porcatus* occur there at a depth of from 70 to 93 feet below the present level of the sea. It is pretty clear that all the littoral beds which are now covered by deep-water shells must have sunk, and, after receiving fresh loads by the gradual accumulation of organic remains during successive generations, have been raised to the height which they at present occupy. It would be difficult to imagine any circumstances under which *Terebratella spitzbergensis* could have found its way to the shore. No Brachiopod has ever been known to be cast up by the tide or waves on a recent beach. This vast quarry has been worked from the time when Linné wrote, and in all probability ever since the land has been cultivated or used by civilized man, for making lime and repairing roads; and yet it is very far from being exhausted. A few years ago the Swedish Government was induced by the representations of Professor Lovén to prevent further devastation on the crown of the hill at Capellbacken, where *Balani* may still be seen *in situ*. Fossils of the same arctic character, but to some extent differing in species according to the nature of the deposit and other circumstances, occur throughout the south of Sweden. Dr. Malm has prepared an elaborate table, showing all the fossils discovered by him in no less than seventy-four localities.

The collections which I examined for the purpose of making out the subjoined list were those of Sir Charles Lyell, Messrs. Thorburn, Dr. Malm, Mr. R. D. Darbishire, and the public museums at Uddevalla and Gottenburg; and I take this opportunity of expressing my best thanks to the gentlemen above named for their liberal and friendly aid. Mr. R. Thorburn was my guide and kind host at Uddevalla. I need hardly say that I personally collected some fossils during my visit to this remarkable place. My list comprises 97 species: viz. Mollusca 83, Polyzoa 2, Cirripedia 4, Echinoderm 1, Annelida 3, Foraminifera 3, Sponge 1. I have no doubt that this number might be increased by further investigations. For facility of reference, and to please my geological friends, I have again arranged the species in alphabetical order, although I cannot help protesting against such an unscientific method of classification.

MOLLUSCA.

Brachiopoda.

Species.	Synonyms.	Remarks.
1. Terebratella spitzbergensis, *Davidson*.	Terebratula caput-serpentis, *Hisinger*.	Enumerated by Lyell as "Terebratula."

Conchifera.

Species.	Synonyms.	Remarks.
2. Anomia ephippium, *Linné*, var. squamula.	A. squamula, *L.*	
—— ——, var. aculeata.	A. aculeata, *L.*	*Fide* Malm.
3. Astarte borealis.	Venus borealis, *Chemnitz*. Crassina semisulcata, *Leach*. C. arctica, *Gray*. C. corrugata, *Brown*.	
4. —— compressa.	Venus compressa, *Montagu*. C. striata, *His.*	Not *V. compressa*, L.
5. —— crebricostata, *Forbes*.	C. depressa, *Br.*	
6. —— sulcata, var. elliptica.	Venus compressa, *L.* V. sulcata, *Da Costa*. C. elliptica, *Br.* C. scotica, *His.* A. semisulcata, *Lovén*.	

Conchifera (*continued*).

Species.	Synonyms.	Remarks.
7. Axinus flexuosus, var.	Tellina flexuosa, *Mont.* Axinus Sarsii, *Lov.*	
8. Cardium edule, *L.*	....	Merging into the variety *rustica.*
9. —— exiguum, *Gmelin.*	C. pygmæum, *Donovan.*	Lilleherstehagen.
10. —— fasciatum, *Mont.*	....	40 feet below the present sea-level (Malm).
11. Corbula gibba.	Tellina gibba, *Olivi.* Mya inequivalvis, *Mont.* C. nucleus, *Lamarck.*	Lilleherstehagen.
12. Cyprina islandica.	Venus islandica, *L.*	
13. Leda arctica.	Nucula arctica, *Gray.* Arca truncata, *Br.* A. glacialis, *Gray* (*Wood's Suppl.*). N. portlandica, *Hitchcock.*	Not *A. glacialis*, Gray (Parry's Voyage).
14. —— minuta.	A. minuta, *Müller.* A. caudata, *Donovan.*	
15. —— pernula, var.	A. pernula, *Müll.* L. macilenta, *Steenstrup.*	
16. —— pygmæa, var.	A. pygmæa, *v. Münster.* N. lenticula, *Möller.*	
17. Lucina borealis.	Venus borealis, *L.*	
18. Lucinopsis undata.	V. undata, *Pennant.*	Lilleherstehagen.
19. Modiolaria discors.	Mytilus discors, *L.* Modiola barbata, *Lyell.*	
20. Mya arenaria, *L.*		
21. —— truncata, *L.*, var. uddevallensis.		
22. Mytilus edulis, *L.*		
23. —— modiolus, *L.*	Modiola papuana, *Lam.* M. vulgaris, *Fleming.*	
24. Nucula tenuis.	Arca tenuis, *Mont.*	Malm.
25. Ostrea edulis, L.	....	Lilleherstehagen.
26. Pecten islandicus, *Müll.*	....	Kuröd (Malm).
27. —— septemradiatus, *Müll.*	P. danicus, *Ch.*	Malm.
28. Pholas crispata, *L.*		
29. Psammobia tellinella, *Lam.*		
30. Saxicava arctica.	Mya arctica, *L.* M. byssifera, *Fabr.* S. grœnlandica, *Potiez & Michaud.*	Principally var. *uddevallensis.*
31. Scrobicularia alba.	Mactra alba, *W. Wood.*	40 feet above sea-level (Malm).
32. Tapes decussatus.	Venus decussata, *L.*	50 feet above sea-level (Malm).
33. —— pullastra.	Venus pullastra, *L.*	
34. Tellina balthica, *L.*	T. solidula, *Pulteney.*	
35. —— calcarea, *Ch.*	T. lata, *Gm.* T. sabulosa, *Spengler.* T. triangularis, (*Wahlenb.*) *Lyell.* T. planata, *His.* T. proxima, *Br.* Psammobia sordida, *Couthouy.*	

CONCHIFERA (*continued*).

Species.	Synonyms.	Remarks.
36. Teredo nana, *Turton.*	Pholas teredo, *Fabr.* T. denticulata, *Gray.* T. megotara, *Forbes & Hanley.* T. dilatata, *Stimpson.*	
37. Thracia papyracea.	Tellina papyracea, *Poli.* Amphidesma phaseolina, *Lam.*	*Anatina myalis*, Lam., in Lyell's list.
—— ——, var. villosiuscula.	Anatina villosiuscula, *Macgillivray.*	Malm.
	GASTEROPODA.	
38. Aporrhais pes-pelicani.	Strombus pes-pelicani, *L.*	Lilleherstehagen.
39. Buccinum grœnlandicum, *Ch.*	B. undatum, *Fabr.* B. boreale, *Brug.* B. anglicanum, *His.* B. cyaneum, *Leach.* B. tenebrosum, *Hancock.*	
40. —— undatum, *L.*		
41. Cerithiopsis costulata.	Turritella costulata, *Möll.* Cerithium niveum, *Jeffr.* C. arcticum, *Mörch.* C. metula, *Malm.*	Not *C. metula*, Lov.
42. Cerithium reticulatum.	Strombiformis reticulatus, *Da C.*	
43. Chiton marmoreus, *Fabr.*	....	Malm.
44. Cyclostrema costulatum.	Margarita? costulata, *Möll.*	
45. Cypræa lurida, *Lam.*	....	Doubtful.
46. Fusus antiquus, var.	Murex antiquus, *L.*	
47. —— latericeus, *Möll.*	F. corneus, *Lyell.* Tritonium incarnatum, *Sars.*	Not *Murex corneus*, L.
48. —— Turtoni, *Bean.*	....	A variety approaching in shape *F. norvegicus.*
49. Lacuna divaricata.	Turbo divaricatus, *Fabr.* T. vinctus, *Mont.*	40 feet above sea-level (Malm).
50. Lepeta cæca.	Patella cæca, *Müll.* P. Clelandi, *Lyell.* P. cerea, *Möll.* P. candida, *Couth.*	The *P. Clelandi* of Sowerby is *Tectura testudinalis.*
51. —— rubella.	P. rubella, *Fabr.*	
52. Littorina litoralis.	Nerita litoralis, *L.*	Lilleherstehagen.
53. —— litorea.	Turbo litoreus, *L.*	
54. —— rudis.	T. rudis, *Mont.*	
55. Mangelia violacea, *Mighel & Adams.*	Defrancia cylindracea, *Möll.*	Malm.
56. —— pyramidalis.	Buccinum pyramidale, *Ström.* Defrancia Vahlii, (*Beck*) *Möll.* Fusus pleurotomarius, *Couth.*	
57. —— Trevelyana.	Pleurotoma Trevillianum, *Turt.* P. reticulata, *Br.*	
58. —— turricula.	Murex turricula, *Mont.*	
59. Margarita grœnlandica, var.	Turbo grœnlandicus, *Ch.* Margarita undulata, *Sowerby & Broderip.* M. carnea, *R. T. Lowe.*	

GASTEROPODA (*continued*).

Species.	Synonyms.	Remarks.
60. Margarita helicina.	Turbo helicinus, *Fabr.*	
	T. margarita, *Mont.*	
	M. vulgaris, *Leach.*	
61. —— striata, *Brod. & Sow.*	M. cinerea, *Couth.*	
	M. sordida, *Hanc.*	
62. —— sulcata, *G. B. Sowerby, jun.*	M. argentata, *Gould.*	
	M. glauca, *Möll.*	
	M. Harrisoni, *Hanc.*	
63. Mesalia? borealis.	Turritella, *Lyell.*	
	Scalaria borealis, *Beck.*	
	S. Eschrichti, (*Holböll*) *Möll.*	
	S. undulata, *Sow.*	
64. Nassa incrassata.	Buccinum incrassatum, *Ström.*	40 feet above sea-level (Malm).
	B. macula, *Mont.*	
	B. coccinella, *Lam.*	
	B. ascanias, *Philippi.*	
65. —— reticulata.	B. reticulatum, *L.*	Lilleherstehagen.
66. Natica affinis.	Nerita affinis, *Gm.*	
	Natica glaucina, *His.*	Not *Nerita glaucina*, L.
	N. clausa, *Brod. & Sow.*	
	N. consolidata, *Couth.*	
	N. septentrionalis, *Beck.*	
67. —— pallida, *Brod. & Sow.*	N. grœnlandica, *Beck.*	
	N. lactea, (*Lov.*) *Ph.*	
	N. livida, *Hanley.*	
	N. pusilla, *Forb. & Hanl.*	Not *Natica pusilla*, Say.
68. —— islandica.	Nerita islandica, *Gm.*	
	Littorina ?, *Lyell.*	
	Natica helicoides, *Johnston.*	
	N. canaliculata, *Gould.*	
69. Odostomia albella.	Turbonilla albella, *Lov.*	40 feet above sea-level (Malm).
	O. rissoides, var., *Forb. & Hanl.*	
70. Patella vulgata, *L.*	....	Hisinger and Malm.
71. Puncturella noachina.	Patella noachina, *L.*	
	P. fissurella, *Müll.*	
	Fissurella græca, *His.*	Not *Patella græca*, L.
	Cemoria Flemingii, *Leach.*	
	Sipho striata, *Br.*	
72. Piliscus commodus, *Lov.*	Pileopsis ungaricus, *His.*	Not *Patella ungarica*, L.
	Pilidium commodum, *Middendorff.*	
	Capulus fallax (and perhaps C. obliquus as the adult state), *S. Wood.*	
73. Rissoa castanea, (var.) *Möll.*	R. exarata, *Stimps.*	
	R. scrobiculata, *Malm.*	Not *R. scrobiculata*, Möll.
74. —— inconspicua, (var.) *Alder.*	R. albella, *Lov.*	
75. —— labiosa, var.	Turbo labiosus, *Mont.*	
76. —— parva, var.	T. parvus, *Mont.*	50 feet above sea-level (Malm).
	R. balthica, *Nilsson.*	
77. —— ulvæ.	Turbo ulvæ, *Penn.*	
78. Tectura virginea.	Patella virginea, *Müll.*	Malm.
	P. parva, *Da C.*	

GASTEROPODA (*continued*).

Species.	Synonyms.	Remarks.
79. Trichotropis carinata.	Murex carinatus, *Laskey.*	
	T. borealis, *Brod. & Sow.*	
	Fusus umbilicatus, *Br.*	
	T. acuminata, *Jeffr.*	
	T. atlantica, (*Beck*) *Möll.*	
	T. costellatus, *Couth.*	
80. Trophon clathratus.	Murex clathratus, *L.*	
	M. Rumphius, (*Mont.*) *Lyell.*	
	T. costatum, *His.*	
	Fusus peruvianus, *Sow.*	
	F. scalariformis, *Gould.*	
81. —— truncatus.	Buccinum truncatum, *Ström.*	
	M. bamffius, *Don.*	
82. Velutina haliotoidea.	Helix haliotoidea, *Fabr.*	
	Bulla velutina, *Müll.*	
	H. lævigata, *Mont.*	
83. —— undata.	Galericulum undatum, *Br.*	
	V. zonata, *Gould.*	
	POLYZOA.	
84. Lepralia Landsborovii, (var.) *Johnst.*	....	Darbishire.
85. —— variolosa, (var.) *Johnst.*	....	Darbishire.
	CIRRIPEDIA.	
86. Balanus crenatus, *Bruguière.*	....	Darbishire.
87. —— Hameri.	Lepas Balanus uddevallensis, *L.*	
	L. Hameri, *Ascanius.*	
	L. tulipa alba, *Ch.*	
	B. tintinnabulum, *His.*	Not *Lepas tintinnabulum,* L.
88. —— porcatus, *Da C.*	B. sulcatus, *Lyell.*	
89. Verruca Strömia, *Müll.*		
	ECHINODERM.	
90. Echinus dröbachiensis, *Müll.*	E. saxatilis, *His.*	Not *E. saxatilis,* Müll.
	E. neglectus, *Forbes.*	
	ANNELIDA.	
91. Serpula norvegica, *Gunnerus.*	....	Malm.
92. —— vermicularis, *L.*	....	Darbishire.
93. —— spirorbis, *L.*	....	Darbishire.
	FORAMINIFERA.	
94. Miliola oblonga.	Serpula oblonga, *L.*	
95. —— trigonula, *Lam.*		
96. Rotalia Beccarii.	Nautilus Beccarii, *L.*	
	SPONGE.	
97. Cliona celata, *Grant.*	....	Darbishire.

A Synopsis of the Bivalved Entomostraca of the Carboniferous Strata of Great Britain and Ireland. By Professor T. RUPERT JONES, *F.G.S., and* J. W. KIRKBY.

After a review of what former observers have published on the Bivalved Entomostraca of the Carboniferous formations, the authors proceeded to point out—1st, a few rather doubtful *Cyprides* or *Candonæ*, from the Coal-measures, 2ndly, *Cytheres*, of which there are about eight species, chiefly from the Coal-measures. 3rdly, *Bairdiæ*, about eight species, mostly from the Mountain-limestone and its shales. 4thly, *Cypridinidæ*, comprising *Cypridina, Cypridella, Cyprella, Entomoconchus*, and *Cytherella*, from the Mountain-limestone: a fine collection of these rare forms from Little Island, Cork, liberally placed at Messrs. Jones and Kirkby's disposal by Mr. Joseph Wright, well elucidate the relationships of these hitherto obscure genera and their species. 5thly, *Leperditidæ*, comprising *Leperditia* (to which genus belong the so-called *Cypris Scotoburdigalensis, C. inflata, C. subrecta, Cythere inornata*, and others, many of them dwarf varieties of one species, and mostly belonging to the Mountain-limestone series); *Entomis* (Mountain-limestone), Devonian and Carboniferous forms of which have been mistaken for *Cypridinæ*; *Beyrichiæ* (from nearly all parts of the Carboniferous system), several species, of which *B. arcuata*, Bean, sp., is the most common; and *Kirkbyæ*, somewhat rare, and chiefly from the Mountain-limestone series.

Leperditia and *Beyrichia* are also Silurian and Devonian genera; they do not appear to pass upwards into the Permian formation. *Bairdia* and *Kirkbya* occur first in the Carboniferous and reappear in the Permian deposits, even in the same specific forms; and *Bairdia* has been freely represented in Secondary and Tertiary deposits, and exists at present. Of the *Cypridinidæ* under notice, *Cypridella, Cyprella*, and *Entomoconchus* appear to be confined to the Mountain-limestone; *Cypridina* occurs in the Permian, and, with *Cytherella*, is found in Secondary and Tertiary rocks and in the existing seas. *Entomis* is a Silurian and Devonian genus, especially characterizing the so-called Cypridinen-Schiefer of Germany.

Notes on some Fossil and Recent Foraminifera, collected in Jamaica by the late Lucas Barrett, *F.G.S. By* Professor T. RUPERT JONES, *F.G.S., and* W. K. PARKER.

In 1862 Mr. L. Barrett, F.G.S., late Director of the Geological Survey of the West Indies, gave Messrs. Jones and Parker some fossil and recent Foraminifera from Jamaica, comprising a few new forms,—some that were previously but little known, and some in finer condition of growth than usual. The recent specimens, from their ascertained habitats, illustrate to some extent the conditions under which the fossil forms were deposited.

One sample of the Fossil Jamaican Foraminifera consisted of several specimens of *Amphistegina vulgaris*; and another, of a few of the same species, with one *Textularia Barrettii* (a new variety of *Textularia*). No locality nor geological horizon was indicated for these. A third sample, from "South Hall Cliff," consisted of two large specimens of *Vaginulina legumen*. Fourthly, a much larger series of Foraminifera from the "Pteropod-marl" of Jamaica affords *Nodosaria Raphanistrum, Dentalina acicula, Vaginulina striata, Frondicularia complanata, Cristellaria calcar, C. cultrata, C. rotulata, C. Italica, Orbitolina vesicularis, Bulimina ovata, Cuneolina pavonia, Vertebralina striata*, and *Lituola Soldanii*. These, however, can be regarded only as an incomplete Rhizopodal fauna.

From the Recent Foraminifera dredged by the late Mr. Barrett from different sea-zones, between 15 and 250 fathoms, on the Jamaican coast, we learn that *Amphistegina vulgaris, Textularia Barrettii, Dentalina acicula, Frondicularia complanata, Cristellariæ*, and *Lituola Soldanii* indicate at least 100 fathoms, and probably more, as the depth at which the Pteropod-marl and the Amphistegina-beds were deposited in that region. Pteropods are found in some sea-muds at similar depths.

On certain Markings on some of the Bones of a Megaceros hibernicus *lately found in Ireland. By* J. Beete Jukes, *F.R.S., F.G.S.*

Part of the skeleton of a *Megaceros* having been procured by Mr. F. J. Foot, of the Geological Survey, from some men who were digging turf in a bog at Legan, south of Edgworthstown, co. Longford, two of the bones and a broken tine of one of the horns were found to exhibit deep cuts as if made with a knife. A femur showed a narrow transverse cut, 4 inches long and $\frac{1}{2}$ an inch deep. A tibia had a wider and shallower indentation, and one exactly corresponding to it was found in the broken horn-tine. When put together, these accurately fitted into each other; and certain mineral stainings existed on the surfaces of both, of precisely similar shape, showing that the surfaces had long been in perfectly close contact.

Mr. Jukes suggested that these indentations might have been produced by the mutual pressure of the two bodies lying in the marl beneath the bog for a long period of time.

According to Mr. Foot's statement, they lay in about 2 feet of shell-marl resting on gravel and clay, and covered by 15 feet of turf; and some of the old men of the neighbourhood said that 25 feet of turf had been formerly removed from the bog.

Mr. Jukes suggested also the possibility of the narrow transverse cut across the femur having been in like manner produced by the pressure of the sharp edge of a piece of antler; and wished to point out the great caution required before appealing to any mere marks or cuts on fossil bones as undoubted proofs of human agency.

He also called attention to the very fresh state of the bones, which had been analysed by his friend M. Alphonse Gages and found to consist of

Inorganic matter (carbonate and phosphate of lime)	58·58
Organic matter (cartilaginous, &c.)	41·42
	100·00

with a density of 1·788. The bone examined was one of the ribs.

On the Neanderthal Skull, or Reasons for believing it to belong to the Clydian Period, and to a Species different from that represented by Man. By Prof. W. King.

The evidences for the first proposition involved in the above title were based on Lyell's description of the Neanderthal cave, which, in Prof. King's opinion, occurs, with one or two negative exceptions, under the same ancient physical-geography conditions as the caverns of the Meuse valley. If the latter became charged with their organic and inorganic contents during the Clydian period *, as must be admitted, it was contended that the Neanderthal infilling belonged to the same great term of geological time, though possibly to its latest division—that of the "Menchecourt low-level flint-implement gravels" †.

In upholding his second proposition, the author first examined the general features of the Neanderthal skull, and showed that, in this point of view, it differed widely from all human crania, either recent or fossil. An examination of the individual *bones* of the skull led to the same conclusion; their form and contours, as well as the relative position of their component parts, were shown to be abnormal to man, but normal to the ape. Indeed, so closely does the Neanderthal skull resemble that of the young Chimpanzee, figured by Busk in the 'Nat. Hist. Rev.' for 1861, as almost to lead to the belief that it does not belong to the human genus: it was admitted, however, that, in the absence of the facial and basal bones, this would be little more than a mere assumption.

Prof. King, noticing next the psychical endowments of man, asserted that they are visibly expressed in the strongly arched form of his cranium—a feature which, though much debased in certain races, characterizes the whole human species.

* In the last edition (5th) of his 'Synoptical Table of Aqueous Rock Groups,' the author proposed the name *Clydian* for the Glacial period.

† See the author's "Attempt to Correlate the Glacial and Postglacial Deposits of the British Isles," &c., in 'The Geologist,' 1863, pp. 168–178.

The Australians and Andamaners possess the dimmest conceptions of their own moral obligations and of the existence of a Godhead—psychical endowments of a lower grade it is difficult to conceive can exist; nevertheless the author believes them to be essentially human: moreover, the brain-case of these races conforms to the highest cranial type of our species. But considering that the Neanderthal skull offers only approximate resemblances to that of man, that it more closely agrees with the cranial type of the Chimpanzee—a creature whose faculties are unimprovable, incapable of moral or theosebic conceptions—Prof. King feels himself constrained to believe that the thoughts and feelings which once dwelt within it never soared above those of the brute.

Thus the author is led to regard the Neanderthal skull as belonging to a creature cranially and psychically different from man; and he proposes to distinguish the species by the name of *Homo Neanderthalensis.*

On some Fossil Fishes from the Permian Limestone of Fulwell, near Sunderland. By J. W. Kirkby.

The object of the paper was to record the discovery of fish-remains in the Upper Magnesian Limestone of the Permian formation, the discovery being of interest especially on account of the remains having been found at a horizon considerably higher in the Permian series than any vertebrate remains had been previously known to occur. The fossils were first noticed in August 1861, in a newly opened quarry, belonging to Sir Hedworth Williamson, Bart., at Fulwell, a mile and a half to the north of Sunderland. The quarry is in the northern slope of the hill, and is not far from another and older quarry. In these quarries the magnesian limestone is largely worked for lime-burning, as it had been in the older quarry for the last sixty years, during which time no traces of any organic remains had been found. In working the lower and inferior strata, in order to keep the new quarry at its proper level, the great bulk of the fossil fish were discovered. Most of them are found in one bed, or zone of beds, of limestone, there nevertheless being several instances of their occurrence both above and below. A similar discovery was afterwards made in the equivalent strata of the old quarry. The same fish-bed also appeared to extend considerably to the north-east—the half-tail of a small fish having been obtained from a stratum of limestone in Marsden Bay. The fossils appeared almost invariably to have belonged to perfect individuals. At least, the entire dermoskeleton, fins, and bones of the head seemed to have been unimpaired up to the period of deposition, though there were instances of distortion by subsequent compression. A pair of individuals were sometimes found together, but the specimens were usually isolated and comparatively rare. Fully nine-tenths of the specimens found belonged to a single species of *Palæoniscus.* The remainder belonged probably to two or three species of the same genus and to a species of *Acrolepis.* The *Palæonisci* were small, the largest being a little over 4 inches in length. The *Acrolepis* seemed to have attained a length of 12 inches. Associated with the fish-remains there had also occurred, rarely, some fragments of plants. These, though imperfectly preserved, appeared to be referable to three species, one of which was a *Calamite,* another an *Ullmannia caulerpa,* and the third was a large reed-like form, whose generic relations were difficult to determine from the discovered fragments. These were the only fossils that had been met with along with the fish. These fish-bearing strata were 150 feet from the top of the Upper Limestone. The discovery carried the Permian Vertebrata from the lower beds of the Permian series of Durham high into the upper, and near enough to the Trias to give to their occurrence, perhaps, more than usual interest. To the paper were appended descriptions of the species.

On the Coal-measures of Sydney, Cape Breton. By J. P. Lesley.

On the Discovery of Rock-salt in the New Red Sandstone at Middlesbrough. By John Marley.

The fresh-water requirements of Messrs. Bolckow and Vaughan in connexion

with their iron-works at Middlesbrough being very large, they commenced, about four years ago, to sink a well or shaft for fresh water. The shaft was carried to the depth of 180 feet. The supply of fresh water being still not considered sufficient, a very large bore-hole was, about a year ago, commenced from the bottom of the shaft. A bore of 18 inches diameter has been put down to the present extreme depth of 1312 feet. The strata bored through form part of the Upper New Red Sandstone or Trias formation, the same as those in which the deposits of rock-salt of Cheshire occur. The rock-salt was first pierced at a depth of 1206 feet, and has been found to form a bed 99 feet in thickness. This bed terminates in a sort of conglomerate, consisting apparently of salt and limestone mixed together.

The quantity and quality of the brine have not yet been fully tested, but the following is an analysis of a sample from the very light-coloured portion of the bed:—

	Per cent.
Chloride of sodium	96·63
Sulphate of lime	3·09
Sulphate of magnesia	0·08
Sulphate of soda	0·10
Silica	0·06
Oxide of iron	trace
Moisture	0·04
	100·00

It is as yet impossible to estimate the extent or area of this deposit. On the north we have, at Castle Eden Colliery, the coal-measures overlain by the Permian; and at Oughton boring, nearer to the Tees, the Trias has been bored into about 500 feet; the Hutton coal-seam, at Castle Eden Colliery, being about 750 feet below the sea-level, and the salt at Middlesbrough about 1250 feet. On the south side of the Tees the Lower Lias is soon met with, and capped by the Upper Lias and Oolitic measures. These measures dip both to the south and north from the Tees.

On the Equivalents of the Cleveland Ironstones in the West of England. *By* CHARLES MOORE, *F.G.S.*

These rocks, with their contained ironstone bands, had been traced by the author from Lyme Regis to Yeovil and Bath. In mineral wealth they formed a marked contrast to those in the north of England; for where the ore was rich enough to work, it was not thick enough, and *vice versâ.*

On the Organic Contents of the Lead Veins of Allenheads, and other Lead Veins of Yorkshire. *By* CHARLES MOORE, *F.G.S.*

The author, having in former papers called attention to the organisms he had met with in the mineral veins which traverse the carboniferous limestones of the west of England, had of late subjected those of Yorkshire to the same scrutiny. In certain veins and fissures in these he had detected numerous organic remains, washed into them by the action of later seas. The most remarkable of these was that of the New Rake vein, the clayey infilling of which was found to contain abundance of "Conodonts"—the small tooth- and comb-like bodies hitherto found only in the Upper Silurian bone-beds, which Dr. Pander had described as fish-teeth, but which Dr. Harley has since established to be of crustacean origin.

Observations of Sir R. I. MURCHISON *upon the Permian Group of the North-west of England, in communicating the outline of a Memoir thereon by* Prof. R. HARKNESS *and himself.*

The Permian rocks, or youngest Palæozoic deposits, which form a natural group characterized by community of animal and vegetable life, occur in various parts of

Europe. He (Sir R. I. Murchison) had applied to them the term Permian in 1841, and, before that time, this group had no collective name. His reason for proposing this name was, that he had found in Russia the stratigraphical and fossil characteristics of the formation spread over a country much larger than France, around the former kingdom of Permia. In the north-west of England there was a remarkable display of rocks, consisting of sandstones and breccias, which were, gradually and conformably, linked together with the magnesian limestone or its equivalent. The lower portion of the deposit, over a large central portion of England, was formerly called the Lower Red Sandstone, the equivalent of the Rothliegende of Germany. The chief fossiliferous member of these deposits was, in the first instance, admirably described by Professor Sedgwick, in his well-known memoir on the magnesian limestone; but that author had not connected the Red Sandstones of St. Bee's Head, Corby, &c., with that magnesian limestone, but had left them in the New Red Sandstone. In Germany, Sir R. Murchison had asserted that overlying sandstones, superposed on the magnesian limestone, formed the upper part of the group; and he showed that in typical sections this mass of sandstones accorded with and passed down into the equivalent of the magnesian limestone, and was separated from the Bunter sandstone of the Trias.

He was now well pleased to find, from the labours of Mr. Binney, followed by those of Professor Harkness, and confirmed by his recent survey of the rocks, that in reality the north-west of England offered a complete confirmation of the tripartite arrangement of the Permian group.

Thus, if several of the small brooks in the Vale of Eden be ascended from west to east, especially that called Hilton Beck, a succession of beds of dolomitic breccia is seen to overlie the enormous mass of the lower portion of this great group, or the Penrith Sandstone. Many of the details have been before explained by Professor Harkness; but he now called particular attention to the value of the recent discovery by his colleague of certain plants in the centre of the group which were absolutely identical with well-known Permian plants elsewhere, and wholly distinct from the carboniferous flora.

Above the limestone and dolomitic breccias came a series of shales or marls, associated with impure magnesian limestone. These passed conformably, and without any break, into the upper sandstone. He was sure Mr. Binney would sustain what he had said in reference to this group being in that district a great Upper Palæozoic Trias.

Again, St. Bee's Head exhibited a thin but instructive portion of the *Rothliegende*, or Lower Red Sandstone. There the breccia was deposited unconformably on the surface of the carboniferous sandstone, which was eroded in a most irregular manner, the breccia entering into all the sinuosities of the lower rock, and showing a complete physical break between the coal-measures and the superjacent Permian strata. Many other English localities offered, indeed, instances of the total separation of the carboniferous deposits, and proved that the Permian was a newer and distinct series, in which breccia entered into the eroded cavities of the water-worn rock. This lower breccia is the representative of the yellow sandstone of Durham, underlying the magnesian limestone occurring near Sunderland and along the coast of Hartlepool.

He would now say a word on a point of importance to gentlemen living in mining districts. Hitherto it had been unknown that the Lower Red Sandstone, or *Rothliegende*, afforded any valuable mineral substance; and, up to this time, geologists had remained unacquainted with the age of one of the most valuable of our ores, the hæmatite or kidney iron-ore of Cumberland and Lancashire. This hæmatite occurs in cavities of the mountain limestone; and it had often been asked, to what age are we to attribute these great infillings? At one time they were referred to a Tertiary period; but Professor Phillips suggested that they were probably connected with the series called Permian.

On this occasion, he (Sir R. I. Murchison) had to announce the discovery of a locality in Furness where the hæmatite was discovered to be in direct connexion with the Permian lower breccia, the "crab rock" of the natives. It was also found that this hæmatite had been frequently worked out by old workmen from cavities under the breccia, thus affording proofs of the value of the suggestion ot

Professor Phillips. This discovery, in enriching the Permian group of England, showed that at the period remarkable in Germany for the eruption of much igneous matter, and very great changes, the era was rife in our country in the elaboration of one of our richest ores.

On the part of Professor Harkness and himself, Sir R. I. Murchison concluded by stating that one of the main objects was to show that large masses of red sandstones, in Westmoreland and Cumberland, which overlie the magnesian limestone or its equivalent, and which, up to this time, have been viewed as New Red Sandstone, must henceforth be classed as Permian; thereby involving a considerable change in all pre-existing geological maps.

On the Chronological Value of the Triassic Rocks of Devonshire. By W. Pengelly, *F.R.S.*

On the Drift Beds of Mundesley, Norfolk. By Prof. Phillips, *F.R.S.*

During his surveys of the Yorkshire coast previous to 1829, the attention of the author had been specially directed to the succession of the later Cænozoic deposits, and, as a general result, he presented in the first volume of the 'Geology of Yorkshire,' published in that year, a series of deposits, the earliest being ossiferous gravels below the boulder-clay, the later being gravels and lacustrine deposits, also ossiferous, above that clay. In the same year Sir C. Lyell informed him of the proofs which he had collected of the "forest-bed" of the Norfolk coast being subjacent to the boulder-clay. To meet these facts by a distinct classification, and others of great exactness collected by Prestwich, Austen, Morris, and others, the author employed, in 1853 *, the terms "preglacial" and "postglacial," in addition to and limiting the term "glacial," which had begun to be generally used.

Having examined in the present year the sections on the Norfolk coast, Prof. Phillips was able to measure the thicknesses, so as to be convinced that the total above the chalk fell short of 400 feet; that, excepting the cases ascertained by Mr. King of bivalve shells in their natural position, no facts of importance appeared which required or even suggested an immensity of time for their occurrence; and that littoral and estuary agitation of water, rather than any considerable movements upward and downward, were indicated as agencies for the preglacial gravels, sands, loams, and "forest-bed." The author was strongly impressed by the want of any real separation between the "Norfolk" rather than "Norwich" Crag and the other laminated shelly deposits which are subjacent to the boulder-clay. The organic remains appear to be not at all opposed to this view; and by adopting one general title for all these beds, immediately above the chalk, in the Norfolk and Yorkshire sections, and treating them as deposits of one varied series of local effects, with but slight changes of level, there is reason to think that a wider basis may be obtained for reasoning on the physical conditions of the "Preglacial" period.

On the Deposit of the Gravel, Sand, and Loam with Flint Implements at St. Acheul. By Prof. Phillips, *F.R.S.*

A recent visit paid by the author to the gravels of the Somme valley had led him to believe that insufficient notice had been taken, in the scheme drawn out to determine their age, of those phenomena of river action which would tend to change the relative positions of the gravel-layers, and that the general lay or position of the beds composing the deposit had not been enough allowed for in reasoning on the agencies concerned. The materials of the deposit were such as could be best accounted for by supposing inundations from melting snows or heavy rains on an uncultivated surface like that of the adjoining hills,—rounded pebbles and hard sandstones from the tertiary beds; rough flints from the chalk; sands and loams, with small flint chippings, from the general surface. The small land and freshwater shells associated with the sands above and mixed with the gravel,

* 'Rivers, Mountains, and Sea-coast of Yorkshire.'

agree with such an origin better than with the supposition of their being accumulated in a lake—for which, indeed, no sufficient evidence appears of any kind.

Assuming, then, a fluviatile action for the arrangement of the deposit, it is first to be remarked that, neither by the abundance of water-shells nor the aspect of the beds does any presumption arise of long-elapsed time during their accumulation. Secondly, it cannot be doubted that the flint implements are of the age of the gravel beds—that is, the age of their latest disturbance; for it is a well-known fact, of frequent occurrence, that an old fluviatile deposit of gravel, sand, and loam is disturbed by even a gentle stream in time of flood, removed and rearranged in the same order in a new situation, and that thus broad areas of recomposed deposit are annually increasing. During such changes, objects like the flint "haches" would be often plunged to the bottom, after having been lying on the top, and may thus be found little worn among objects which may have experienced longer agitation and "frottement."

But the age of this gravel is not necessarily so very great as it must be if the beds were deposited at the high level which they hold, and the valley subsequently excavated by the river. This probably did not happen; the beds are not level—they slope towards the river 1°, 1½°, 2°, and 2½°; this slope proves them to have been *angularly elevated*; and, by examining other sections in the same valley, it appeared to the author that the line of the Somme is marked out by a fault, and that other angular movements of the same kind in modern geological times have marked out the other exactly parallel valleys on each side of the Somme, between the well-known anticlinal axes of Boulogne and the Pays de Brai. The author is disposed to accept as *probable* the contemporaneity in Picardy of the "flint-knappers" and the extinct Rhinoceros, but to refuse to the deposit *proof* of more than a few thousand years of antiquity.

On the Recent Discovery of Gold near Bala Lake, Merionethshire. By T. A. Readwin, *F.G.S.*

The discoveries of gold in Merionethshire have of late been rather frequent. In some instances the appearances have been of such a character as to justify expectations of profitable results. Last year the author enumerated the gold localities of the neighbourhood of Dolgelly; now he noticed a recent discovery of gold near the beautiful lake of Bala (*Llyn Tegid*). About five miles from Bala, on the north-west side of the turnpike-road leading to Dolgelly, and about two miles from the village of Llanuwchllyn, nearly opposite the western end of the lake, is a prominent hill, known as *Castell Carn Dochan*. At the top of this hill are the ruins of a castle of the olden time, and at the foot of the hill runs the swift little river Lew (*Avon Lew*) on its course to the lake. Geologically, the district is similar to the "Dolgelly Gold District," namely, the Lower Silurian rocks penetrated by large bosses of greenstone. The Maps of the Geological Survey, LXXIV. S.W. and LXXV. S.E., show a continuation of rocks to this spot, in a north-easterly direction, of precisely the same character as at Cwmheisian, Dolfrwynog, Cefn Coch, Tyddyn-glwadis, &c., a distance of six or seven miles. At Castell Carn Dochan Mine there is a very remarkable auriferous quartzose lode. It runs nearly N.E. and S.W., and has a dip to the south. This lode is exposed to view for about twelve fathoms, showing gold in specks nearly the whole distance. The lode-stuff is for the most part free from sulphurets of lead, zinc, and copper. Occasionally metallic gold is found richer than a large specimen which was exhibited. The quartz has a different appearance from that at Clogau and Dolfrwynog, and resembles more closely that at Clunes in Australia. Some boulders of quartz weighing from 2 to 4 cwt. have been broken up and found to contain visible gold throughout. The largest boulder had been built into a wall, near the spot where it had fallen. The upper portion of the lode appears to have slipped over the lower and down the face of the hill, leaving behind it a record of where it had been in characters of gold. Many tons weight of this lode-stuff have been collected, some of which has yielded gold at the rate of 18 oz. to the ton. It is interesting to notice large loose masses of greenstone lying about, having upon them incrustations of quartz, spangled with particles of gold. The débris, of which there is a considerable quantity, yields gold

of equal value with the lode-stuff. Specimens of quartz have been found showing gold as rich as any that has been found at Clogau, where £32,000 has been realized from the gold-produce of less than 1300 tons—a result, he believed, unparalleled in the world's history of gold-quartz mining. Operations have been commenced at the mine, by driving an adit into the face of the hill to cut the lode at a depth of about 20 fathoms. This level has been driven to within six feet of the lode, which, if found as rich at that depth as the sample exhibited, very probably may give as satisfactory results as the St. David's Lode at Clogau. The gold is not associated with sulphurets in excess, so that its extraction is exempted from the difficulties generally attending the various processes of amalgamation. This is an important fact, and greatly enhances the commercial value of the discovery*.

On some Remains of Bothriolepis. *By* G. E. Roberts.

The fossils described consisted of two casts of the central cephalic buckler, previously unknown, and several other bones and plates of the head of this great fish. Agassiz, Pander, and Eichwald had described the dorsal scutes; but no portion of the head, save the jaws, had come under their notice. The position of *Bothriolepis* among the Dendrodic Cœlacanths was noticed; and although its affinity with *Asterolepis* seemed probable, too little was known about the family to warrant the setting up of any one species as a type. The plates covering the head were a quarter of an inch in thickness and of great strength, the external ornament consisting of excessively fine radiating lines and sinuous ridges. The specimens were obtained from the yellow sandstones of Alves and Newton in Elginshire, their exact stratigraphical position being beneath the reptiliferous and footprint beds, of presumed Upper Devonian age, and in the lower part of the section described by Professor Harkness. *Bothriolepis* exceeded *Asterolepis* in size, the length indicated by the fossil remains being from twenty to twenty-five feet.

The specimens exhibited were collected by Dr. Taylor, of Elgin, the Rev. Dr. Gordon, of Birnie, and Mr. Smith, of Inverness.

On the Discovery of Elephant and other Mammalian Remains in Oxfordshire. By G. E. Roberts.

A considerable number of elephant and other mammalian bones have recently been met with in a cutting upon a new line of railway passing through Thame, in Oxfordshire. By the kindness of Mr. J. J. Wilkinson, a gentleman connected with that line, a large portion of those exhumed has been forwarded to the Geological Society. They were taken from a coarse rubbly gravel, mixed with stiff clay, about 13 feet from the surface. The section forwarded by Mr. Wilkinson gives a surface-clay, lightish yellow in colour, and with a sandy bottom 11 feet in thickness, lying upon the gravel, the average thickness of which is 2 feet 6 inches, and which passes downwards into a light-coloured sand. About 10 feet down in the clay a vase was found, of coarse earthenware, full of small bones; and just above the gravel another vase of coarse brown ware. The gravel extended linearly for 60 yards, and was slightly dome-shaped. Part of the bones have been submitted to Dr. Falconer, who has recognized *Elephas primigenius* of the Siberian type,—teeth and other remains rather abundant; *Elephas antiquus*; a large species of *Bos* (*primigenius*? or *priscus*?),—top of radius, tibia, and horn-core; many bones and teeth of *Equus Caballus fossilis*, including a finely preserved tibia of great size, and a portion of another still larger; and some good fragmentary specimens of the horns of *Cervus elaphus*. Still more important mammalian remains have been obtained by Mr. Codrington, F.G.S.

On a Help to the Identification of Fossil Bivalve Shells. By H. Seeley, *F.G.S.*

The author suggested that, if the number of hinge-teeth possessed by these shells was written down in formulæ, similar to the plan in use for mammalian teeth, much

* February 1864, the lode is cut in the level 18 fathoms below where the gold was found. It is 3 feet wide, and shows gold occasionally.—T. A. R.

aid in determining species and also in grouping families of the Mollusca would be the result. Hinge-teeth, which were persistent in form, could be indicated by ordinary numerals, and variable teeth by accentuated numerals. In drawing out such a scheme care was taken to note the position of the teeth, whether anterior or posterior to the umbo. He considered that the plan, if adopted, would simplify the definition of a genus.

[The paper is printed in the 'Geologist' for February 1864.]

On a Section of the Strata from Hownes Gill to Cross Fell. By T. Sopwith, *F.R.S.*

The strata of the lead-mining districts of the North of England extend from beneath the coal-bearing strata of the Northumberland and Durham coal-fields at Hownes Gill to the mountain of Cross Fell in Cumberland, and were exhibited in a section taken from east to west over the important lead-producing districts of East and West Allendale and Alston Moor. The Fell-top Limestone is seen to form nearly the summits of the highest hills, and, beneath, a great thickness of siliceous and argillaceous strata intervenes between it and the Great Limestone. This forms one of a series of limestone strata, in which large quantities of lead have been produced. Several details relating to this section were verbally explained by Mr. Sopwith.

On Models illustrating Contortions in Mica-Schist and Slate. By H. C. Sorby, *F.R.S.*

One of the models was formed of alternating bands of black and grey vulcanized india rubber, which were firmly held at one end by a brass clamp, and were free at the other, unless held by the fingers. When this was bent, it showed that the exterior layer was stretched and the inner compressed. Yielding in this manner, no secondary contortions were produced, but merely a simple band, as in contorted slate rocks. The other model was constructed with alternating bands that could not be stretched or compressed, by making use of the india-rubber enclosing canvas, and was firmly held at both ends by brass clamps; and, when this was bent, various secondary contortions were produced, similar to those met with in many varieties of contorted mica-schist.

Description of a Sea-star, Cribellites carbonarius, *from the Mountain Limestone Formation of Northumberland, with a notice of its association with Carboniferous Plants. By* George Tate, *F.G.S.*

This Asteroid, the first recorded from the Mountain Limestone, is an impression of the upper surface, in a fine-grained micaceous sandstone. It is named *Cribellites carbonarius*; and the following characters are observable:—Rays five, rounded, lanceolate, five times as long as the disk, ridged in the centre, covered with longitudinal rows of reticulating tubercles: disk small and tuberculated. The disk is only 0·3 of an inch in diameter, while the rays are 1·5 inch in length. A circular impression in the disk may be the impression of the Madreporiform nucleus. In the form of this Asteroid, and in the characters observable, it is similar to *Cribella rosea*, Müller; but the rays are proportionally longer, the disk smaller, and the tubercles much nearer to each other than in the recent analogue. The sandstone from which the fossil Sea-star was obtained lies 20 feet above the Shilbottle coal, and about 600 feet below the base of the millstone grit, being in the upper part of the Mountain Limestone formation, which, in Northumberland, is about 3000 feet in thickness. In this sandstone there also occur *Strophomena crenistria* and the remains of carboniferous plants. In the same locality, somewhat higher in the series, there is another sandstone-bed, in which are vast numbers of *Strophomena crenistria*, associated with species of *Sigillaria, Lepidodendron, Calamites, Knorria*, and the *Stigmaria ficoides.* One or two other similar facts will help to illustrate the geological history of the Coal era. At Budle a metamorphosed shale, 30 feet in thickness, overlying a limestone, is in the under layers crowded with marine organisms, such as *Griffithides farnensis, Euomphalus carbonarius, Bellerophon Urii,*

B. decussatus, and *B. striatus*, *Leda attenuata*, *Posidonia Becheri*, *Strophomena crenistria*, *Chonetes Hardrensis*, and *Lingula squamiformis*; but, as we ascend upward, stray fragments of plants are mingled with these organisms, and on an endogenous leaf we find the marine Annelid *Spirorbis carbonarius*; further upward, the marine organisms decrease, and the plants increase; and in the upper part of the deposit the marine organisms disappear, and numerous fragments of *Stigmaria ficoides*, *Bechera*, ferns of the genus *Sphenopteris*, and endogenous leaves are spread out between the layers of the shale. The Mountain Limestone of Northumberland is prolonged in a narrow tongue for a few miles along the Berwickshire coast, and there, too, is a shale-bed showing a similar assemblage of organisms; the lower layers contain *Chonetes Hardrensis* and *Nucula gibbosa*, but the upper layers are filled with *Sphenopteris*, reed-like stems accompanied with *Spirorbis*, *Holoptychius Hibberti*, and other fish-remains, and *Estheria striata*, var. *Tateiana* (Jones). Such sections indicate a change of conditions taking place while the beds were in course of deposition: at first the conditions were undoubtedly marine, but they became estuarine from some unknown cause—probably from a gradual alteration in level and in influx of fresh water, and passed eventually into entirely freshwater conditions.

On the Origin of the Jointed Prismatic Structure in Basalts and other Igneous Rocks. By Professor J. Thomson, *M.A.*

The author gave reasons against the prevailing views of the origin of the jointed prismatic structure of basalt and other igneous rocks, which are founded on the supposition of a spheroidal concretionary tendency in the material during consolidation; or on this, combined with a tendency to split into prisms by shrinkage, such as is met with in the drying of clay or starch. 1st. No reason has been assigned, and he believes none is conceivable, why the supposed centres of concretionary action should be arranged in straight or nearly straight rows, like beads on a vast number of parallel strings. 2nd. Even if the centres were so arranged, still we ought to expect, under the supposition in question, that the centre of a spheroid of one column would often be in front of the division between two spheroids of an adjoining column, and that thus the sides of the columns would be serrated with indentations and protuberances at the cross joints instead of being smooth as they actually are. He supposed that the columns of basalt have been formed by splitting through shrinkage of a very homogeneous mass in cooling; and that the cross joints are fractures which have commenced in the centre of the column, and advanced to the outside as a circle increasing in diameter. This mode of fracture he thought is evidenced by various markings and other indications on the stones. They usually show a remarkably symmetrical appearance round the outer part of their cross joint faces; presenting an appearance like a complete circular conchoidal fracture, often with rays from the centre, such as are seen in the ordinary conchoidal fracture. In order to produce the cross fractures commencing in the centre, he supposed that a longitudinal tensile stress must have existed in the columns previously to the cracking of the cross joints. He would not venture to explain the origin of this tensile stress; but suggested that, perhaps, after the column was formed, chemical action, caused by infiltration of water, might cause a slight expansion of the outside of the column, and so introduce the internal tensile stress.

On "the Wash," a remarkable Denudation through a Portion of the Coal-field of Durham. By Nicholas Wood, *F.G.S.*, *President of the Institute of Mining Engineers of the North of England; and* Edward F. Boyd.

In the introductory part of this paper the authors observed that in all parts of the earth numerous proofs are exhibited of the abrading action of water, by which not only the valleys and softer strata, but the more consolidated strata also and the highest elevations of the land have been abraded; and, by this agency, vast accumulations of sand, gravel, clay, and rounded boulders have been formed and distributed, by means of floods, over different parts of the earth's surface. The authors do not wish, in this communication, to determine the precise mode by which these accumulations have been formed, but only to point out the universality of

their occurrence. More particularly they wish to show that some of the phenomena exhibited by the mining-operations carried on in this district most materially bear on this question. They state that the numerous opportunities which have occurred to them of collecting information respecting those superficial gravels, clays, and sands which are spread over the coal-field of Durham, and also the frequent opportunities they have had of observing the abrasion or denudation of the strata of the district, and especially of a remarkable one locally termed "the Wash," which cuts through a considerable portion of the Durham coal-field, have induced them to lay the result of their experience before the members of the British Association.

It was stated by the authors that this wash or drift can be traced through the coal-field, from the vicinity of the city of Durham, in a northerly direction, to the river Tyne, near Newcastle; that it is traversed a considerable portion of this distance by the present valley of the Wear, until, having passed Chester-le-Street, it follows the course of the Team valley, and terminates at the junction of the latter stream with the Tyne. This communication was illustrated by a plan of the whole district traversed by "the Wash," and a series of cross-sections exhibiting in detail the depth of the denudation of the strata, the nature of the deposits, and other information relative to the materials accumulated in this old valley.

The details of the various cross-sections show that the deepest portion of the denudation was along the eastern or dip side of the valley, and that the basseting or outcropping edges of the strata on that side are more upright and abrupt than those on the opposite side; that all the stones and pebbles, from their rounded appearance, bear marks of long exposure to the abrading action of water in motion; that no traces of shells, bones, or other organic remains were observed; and that the pavement or bottom of the valley on which the accumulated materials rest bears evidence of the great power of the water which carried the débris along its channel. The surface of some of the harder sandstones met with in sinking through the gravel and clay was furrowed and polished in rough and scarred outlines, and the coal-seams, where exposed, were either upright, adjoining the denudation, or worn and rounded off, as if acted on by the movement of harder bodies across them; but frequent cases occurred where the seam of coal, when traced to its termination against the clay, had the upper portion of it destroyed by abrasion, and portions of that nearer the floor remained, the intervening parts being filled up with clay, and boulders, and broken pieces of coal, frequently of a large size. The rounded boulders and pebbles found disseminated and mixed with the masses of clay consist generally of hard sandstone, limestone, ironstone, &c., of the carboniferous strata occurring to the westward. The lowest point of excavation of this valley, being 140 feet below the sea-level, points to a former higher elevation of land than at present.

The authors suggest that the feeders, by which the body of waters found their way into "the Wash," may be traced in the shape of branches or tributaries in more than one direction. One extends up the rivulet of Urpeth, another from Durham to Bishop Auckland and westward on the line of the river Wear, and another probable branch extends considerably more to the east, although the authors suggest the flow from the latter may possibly have been in a southerly direction and towards the Tees.

The authors do not decide whether this denudation has been caused by running water or glacial action, though the uniformity of the bed of the denudation and its moderate rate of inclination would lead to the latter opinion. They would not, however, lose sight of the fact, that a body of water which could cover the top of the deep deposit, 300 feet thick, which occurs at Durham, must have had some effect in the production of a current of considerable force down the course of the Wash.

The peculiar relation of the Wash to the existing river-systems and present drainage of the country is also pointed out, and a comparison is made of the uniform rate at which the present river Wear and the old Wash channel decline to the north, until the Wear suddenly leaves the line of the old valley and flows to the sea through a gap in the magnesian-limestone escarpment, branching off at an elevation of 100 feet above the level of the Wash, through the solid strata.

The authors sum up the result of their communication by the following remarks:—That, at some former period, a current of water or masses of glacial ice passed down the valley of the Wash from the site of the city of Durham to the river Tyne, near Newcastle; that such a current or glacial action denuded the solid strata for a depth of from 150 to 200 feet, and that at its debouchure into the valley of the Tyne it excavated or denuded the solid strata to the depth of 140 feet below the present high-water level at Newcastle, and consequently very considerably below the present level of the sea; that such denudation or wash has been subsequently filled up by the detritus partly produced on the spot and partly brought from distant localities; and that the present drainage of the county passes over this detritus in some places at a level of from 100 to 140 feet above the bed of the ancient Wash, and at the latter depth below the present high-water level of the North Sea.

It is also somewhat extraordinary that though the present drainage of the county (the river Wear) passes along the general line of the ancient river, and at about 100 feet higher level, it does not follow the precise line of the Wash, but occasionally diverges in a zigzag direction, especially near Durham: passing through the solid rock in preference to keeping the straight line of the Wash, it again falls into the straight line of the Wash, along which it passes for a considerable distance, and, at Chester-le-Street, diverges almost at right angles to the line of the Wash to the eastward, and passes into the sea at Sunderland, preferring that course through the magnesian-limestone rock to keeping the straight line of "the Wash" northward along the river Team, though there is a descent of upwards of 50 feet to the river Tyne in the Wash; the present drainage of the country by the river Team being 140 feet above the level of the Wash at its debouchure at the river Tyne, and 140 feet below the present high-water level of that river.

ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

Address of Professor Balfour, *F.R.S., President of the Section.*

In opening this Section of the British Association, it may be proper to make a few introductory remarks. At some of the meetings the President has given a *résumé* of the recent progress of the department over which he presides. I regret that I am unable on the present occasion to follow such a good example. The comparatively recent date at which I was requested to occupy this honourable position, and my University engagements, which were only concluded about a fortnight ago, have prevented me from attempting to do more than make some general remarks on the value and importance of the investigations embraced in Section D. The subjects are *Biological*—having reference to the structure, physiology, and distribution of living beings. Man, animals, and plants are alike included within the scope of our researches. Although our Section is separated for convenience from that of geology, nevertheless they have important bearings on each other. The study of palæontology cannot be prosecuted without a thorough knowledge of the anatomy, mode of growth, and geographical distribution of the plants and animals of the present epoch. In fact, the study of fossil plants and animals ought to constitute a part of every course of botany and zoology. Geology, in place of being reckoned a distinct science, may be considered as the means by which the departments of mineralogy, botany, and zoology are combined in one harmonious system—embracing the natural history of the globe. Rash geological statements and conclusions often arise from imperfect knowledge of the sciences included in our Section. Fronds of ferns of different external forms have been described as distinct fossil species or even genera,—the geologist not knowing that very different forms of frond are exhibited by the same species of fern in the present day. Again, another error has arisen from the same form of frond being considered as indicating the same species, whereas the same form does occur in different *genera* in the present flora; and these can only be distinguished by the

fructification, which, in fossil ferns, is rarely seen. So also the same forms of shell may belong to different *genera*,—the only distinction being founded on the teeth or some other character of the *animal* inhabiting the shell,—and such characters are of course totally lost in the fossil. The cortical markings of plants have been made to characterize different genera and species, while the fact that dissimilar markings occur on the same bark, according as it is viewed on its inner or outer surfaces, has often been neglected. Again, the presence of a palm-leaf might be considered by the geologist as indicative of a very hot climate, from his not knowing that some palms occur at high latitudes, and others are met with on mountains associated with cool forms of Coniferæ. These and numerous instances might be adduced to show the necessity for a perfect acquaintance with the present fauna and flora in all their details, before the geologist can determine fossils, or the character of the climate of palæontological epochs. There is a mutual bearing of all the natural sciences on each other, and the student of nature must take a comprehensive grasp of all.

The natural sciences have always occupied a prominent place in the Proceedings of the British Association. The subject is in itself popular, and is interesting to all classes. Much has been done in this Section to advance the sciences of zoology and botany, and to stimulate naturalists in their investigations.

A feature of the Association, which requires special notice, is the procuring of reports on different departments of science, and the aiding and encouraging of naturalists in carrying on researches which require much labour and expense for their prosecution. Many a deserving young naturalist has thus been enabled to advance science and lay the foundation for future fame and promotion.

Another important feature of the Association is the bringing together men of science, and promoting free personal intercourse. Perhaps more good has been done by this than even by the reading of papers. Interchange of thought by oral communication, and the opportunity of frankly stating difficulties and of asking questions, are most valuable to men of science,—especially when they are congregated from various parts of the world. Friendships too are cemented, and asperities are softened, by coming into contact with fellow-labourers in the same great field. No doubt, there have been occasional unpleasant altercations at our meetings; but even these have been ultimately turned to good account. Explanations are made, opinions are canvassed, and truth is finally elicited. "For as iron sharpeneth iron, so the countenance of a man his friend." But, it has been remarked, iron does not sharpen iron unless it is brought into contact with its fellow, and one be made to act sharply and keenly on the other.

In former days keen disputes took place among geologists in reference to the formation of rocks. The igneous view propounded by my distinguished relative, Dr. James Hutton, was supported warmly by some, while the aqueous view was espoused by others. At length, by a combination of fire and water, truth was elicited, and the minds of geologists were to a certain extent composed. The relations and position of rocks,—the continuity of formations,—Cambrian and Silurian rocks,—coal and shale,—glacier motion,—the definition of species, their permanence or variability, and their origin,—embryogeny and cytogenesis in plants and animals,—flint-hatchets,—the age of man,—and many other points, structural and physiological, have been, and some are still, discussed with great keenness and even with acrimony. But out of all this, as in former cases, truth will at length come forth. The storms which now and then agitate the natural-history atmosphere will purify it. Like the mists on the mountain, which bring out in bold relief the noble rocks and ravines of the craggy summit, so these disputes, even while they are carried on, bring out some phenomena of interest which had been previously invisible. The lightning's flash from the dark cloud may discover to us some prominent object which had been overlooked in the calm sunshine. But ere long the storm will cease, the mists will be dissipated, and then the unclouded summit will appear in all its majestic clearness. So when the obscurity cast around science by the disputes of combatants shall have passed away, the truth will shine forth to the calm eye of the philosophic observer in all its beauty. In such polemics we are not to fight merely for victory or for the advancement of our own fame, but for the great cause of truth, which alone will prevail at last.

No studies are better calculated to promote friendly intercourse. The investigation of God's works is well fitted to calm unruly passions, and to promote humility and harmony. In speaking of the effects of the practical prosecution of botany, the late Dr. Johnston of Berwick remarks:—"There is a preordained and beneficial influence of external nature over the constitution and mind of man. He who made nature all beauty to the eye implanted at the same time in His rational creatures an instinctive perception of that beauty, and has joined with it a pleasure and enjoyment that operate through life. We are all the better for our botanical walks when undertaken in the right spirit. They soothe, soften, or exhilarate. The landscape around us becomes our teacher, and from its lesson there is no escape: we are wooed to peace by the impress of nature's beauty, and the very air we breathe becomes a source of gratification and pleasure." Many a time, while carrying on botanical researches in the wide field of nature, and visiting the alpine districts of this and other lands, have I felt the force of these remarks.

On the last occasion that I presided over Section D,—viz. at Liverpool in 1854,—I was associated with my late deeply lamented colleague, Edward Forbes, who was President of Section C; and on looking back to his career, I would hold him up as a bright example of a true naturalist, who took a wide and expanded view of Nature in all its departments, and at the same time exhibited such a genial spirit as endeared him to all. Once and again was I associated with him in scientific rambles and in meetings of naturalists, and I have seen the tact with which he subdued the *perfervidum ingenium* when misdirected, and calmed the turbulent spirit when self-esteem prevented the due acknowledgment of another's merits. He was truly unselfish, and never failed to recognize and encourage merit wherever he could detect it. I have elsewhere remarked, that with all his knowledge he combined an affability, a modesty, a kindness which endeared him to every one. No student of nature was beneath his notice; no fact recorded by a pupil, however humble, was passed with neglect. He was ready at all times to be questioned, and was prompt to point out any spark of merit in others. He had no jealousy, and never indulged in attacks upon others. He gave full credit to all, and he was more ready to see the bright than the dark spots in the character. Even to those who criticised him severely, he bore no ill-will: he certainly did not return railing for railing. He had a truly generous spirit, and was totally devoid of narrow bigotry. He was desirous of promoting science independent of all selfish views. He loved it for its own sake. Would that his example was more followed by all of us!

When we look at the changes which are constantly taking place in the views of naturalists as science advances, we cannot but feel the need of modesty in the statement of our opinions. While we give our views, and the reasons for adopting them, let this be done without dogmatism or asperity, ever remembering that our conclusions may be modified or altered by future discoveries. Such anticipations, however, should not paralyse our efforts. Science is advancing, facts are being accumulated, and year after year a noble structure is being reared on a sound foundation. It requires now and then a master-mind to bring out great generalizations, and to give a decided impetus to the work. Facts must be carefully weighed, and knowledge must be accurate and extensive; otherwise a genius in science is apt to bring forward rash generalizations and to indulge in unfounded speculations.

The imagination is disposed to run riot when a grand vista seems to open before it, and it flies on heedlessly to the terminus, without surveying the intermediate ground. We do not ignore speculation, but we recommend at the same time cautious induction—a sifting of facts, and of their relation to each other.

Natural-history sciences are now assuming an important place in education. They are not confined as formerly to medical men, but they enter more or less into the preliminary studies of every one. While classics and mathematics ought to have an important place in our schools and colleges, natural history cannot now be neglected. Universities which formerly ignored it are now remedying their error in this respect, and we may ere long hope to find it occupying a still more important position in educational institutions. The possession of university honours is now connected to a certain degree with a knowledge of nature, and a Master of Arts as well as a Doctor of Medicine is supposed to know something of

the objects in the material world with which he is surrounded. The establishment also of special degrees in science is a step in advance for which we are indebted to the University of London. Natural sciences are particularly valuable in mental training. They promote accuracy of observation and of description. They teach the student to look at the objects around him not with an idle gaze, but with an intelligent discrimination. They ensure correctness of diagnosis, and encourage orderly and systematic habits.

The British Association, in its perambulations, does much good by bringing such subjects prominently under the notice of directors of educational institutions in various parts of the country. It stirs up many to see the value of this kind of knowledge, and gives practical illustration of its bearing on the ordinary business of life. Thus the Association has an important influence on the town in which it meets, not merely by what it does during its sittings, but also by its after-effects on the population. The very preparations made in the locality for the meeting have often been productive of much permanent good. They have been instrumental in bringing together collections which have formed the nucleus of a local museum, and they have been the means occasionally of introducing sanitary measures of the highest benefit to the inhabitants.

In conclusion I would remark, that the contemplation of the works of God is only second to the study of His Word. It was too often supposed that science and religion were opposed. Dr. James Hamilton remarks:—"Science and religion long stood in doubtful opposition. There was much needless dread among the believers in the one, and much needless boasting from the disciples of the other. Religious men expressed their convictions with the mingled caution and asperity of fear, while scientific men hastened, with an air of unholy triumph, to place their discoveries in direct opposition to the statements of Scripture. Time has done much to reverse these positions. The progress of investigation, the growth of scholarship, the enlargement of knowledge, have removed many of the objections formerly brought against Scripture, and enabled its defenders to give them full and satisfactory answers. Now there is less of unbelieving dread on the one hand, less of unseemly boasting on the other. It is no longer necessary to scoff at revelation in order to appear witty, or required to question its truth in order to appear learned. The advocates of a heaven-given Bible have learned to use the weapons of their opponents; they can walk abroad among the mysteries of science with as fearless a step as the most daring unbeliever, and are able to claim the result of its highest teaching in proof of the statements and doctrines of the Word of God. The attempts to produce opposition between the works and the Word of God have utterly failed. The longer it continued, the greater became their harmony; as they approached, their enmity was laid aside—they discovered they were friends. The clear eye of Science looked on the serene face of Religion, and received somewhat of her benignant expression; the pale brow of the ambitious student has bent over the page of Revelation, and his eye blazed with light brighter than the fire of genius, for it was radiant with the hopes of a coming immortality."

It is clear that religion and science must be in harmony. The works and the Word of God cannot be at variance. The two books of Revelation and of Nature are complete and perfect as regards their author. In the one we have a revelation in regard to matters of eternal moment—that Word which is true from the beginning, which cannot be broken, and which abideth for ever,—on the discussion of which we do not enter at the meetings of the British Association. As concerns the great truths thus revealed, he that runs may read. The Book is not intended to teach science. "The Bible, however, never does violence to facts, nor to the principles of sound natural philosophy. Never in one single instance will you find it in opposition to the just ideas which science has given us regarding the form of our globe, its magnitude, and its geology. There is no physical error whatever in the Scriptures; and this transcendent fact, which becomes more admirable in proportion as it is made the subject of closer investigation, is a striking proof of the inspiration which dictated them, even to their least expressions."

The other book has been placed before us in order that it may be examined by the intellectual powers of man, and that its truths may be gradually evolved in the course of ages. The investigation of these truths, depending on man's powers of

observation and research, must necessarily be imperfect. The pages of it are opened by one generation after another. Much error may be mixed up with these researches, and we cannot appeal to an authoritative revelation on these matters.

There may be science falsely so called—incomplete investigations—which at first sight may appear to be at variance with statements in Scripture. But all supposed opposition will disappear as science advances. We have no fear of true science. We cannot too carefully or too minutely interrogate God's works. There may be a mistaken interpretation of the physical facts mentioned in God's Word, and there may be difficulties as regards them which it is not easy to unravel, and which we may not now be able to explain. So far as our faith is concerned, there is no cause for alarm as to the teachings of science; and in regard to minor points, there are no contradictions in the two books. Although it is not in these meetings that we discuss religious questions, still every Christian naturalist must in his own mind weigh the bearings of science on that religion which tells him of new heavens and a new earth, and on which rest all his hopes of a blessed immortality.

Botany.

Description of the Fruit of Clerodendron Thomsonæ (*Balf.*), *from Old Calabar. By* Professor Balfour, *F.R.S.*

This Verbenaceous plant was sent from Old Calabar by the Rev. W. C. Thomson, and had been described and figured by Professor Balfour from specimens grown in the Edinburgh Botanic Garden. The plant has since perfected its fruit, and Professor Balfour gave a description of it, illustrated by drawings. When in fruit, the plant presents a showy appearance, owing to the scarlet covering of the inner surface of the achenes. The style of this plant in the young state is terminal, and the four achenes are concrete. As the carpels advance in growth, they separate and the style falls off. On cutting across the four achenes, we observe at their junction a red cellular coat. This coat increases in size, becomes succulent, and finally separates the achenes so as to make them spread out in a horizontal cruciate form, being united only at their bases. The cells of the scarlet mass contain oil-globules.

Description of a New Plant-house. By T. Bewley. *Communicated by* N. B. Ward, *F.R.S.*

The principal feature was a double roof, by means of which the heat was retained to such an extent that it took several nights of severe frost to bring down the temperature from 52 to 48 degrees. The effect of this arrangement upon some plants was really wonderful, and it enabled the author to grow tropical plants towards the roof, while plants requiring a more temperate atmosphere were grown below.

On Proliferous Cones of the Common Larch. *By* John Hogg, *M.A., F.R.S. & L.S., &c.*

The author exhibited many specimens of the cones of the common Larch which presented an abnormal mode of growth. He first observed this proliferous growth in two or three cones from a young tree, wherein the stalk of the cone had grown through the cone itself to an extent of about two inches, in the autumn of 1858; and in the following spring he forwarded them to Sir W. Hooker for the Museum in Kew Gardens, where they still remain.

The specimens he now showed were gathered by himself off several young larches in October 1862, in another plantation; and the shoots from the extremities of the cones had in some extended to full $10\frac{1}{2}$ inches, which, as they were well covered with leaves and buds, seemed perfectly healthy, and capable of growing into strong and regular branches.

This healthy condition forbade him from attributing the singular proliferousness to *disease*, but assured him that it originated in an *exuberance* of *growth*, caused or increased by the rainy summer of 1862.

The author, for the purpose of ascertaining the mode of growth of the stalk through the entire cone, had three cones sawn through longitudinally, and in all the same undivided growth was proved. The cones were quite healthy, and the seeds well formed and advancing to maturity.

List of rarer Phænogamous Plants discovered in the South-East of Durham since 1829. *By* JOHN HOGG, *M.A., F.R.S., F.L.S.*

In the year 1829 the author communicated some catalogues of natural history, as an "Appendix" to the second edition of the History of Stockton-on-Tees. At the last Meeting of the British Association at York, he enlarged the "Catalogue of Birds," by including all the more rare kinds which had been recently detected in that vicinity. So it was his intention on the present occasion to have done the same with the rarer Phænogamous plants that he had met with in the south-eastern portion of the county of Durham since 1829, and to have added some descriptive notices respecting the rarest, with their habitats. Time, however, had failed him; and consequently he could only present to this Section a bare list of the different plants alphabetically arranged.

Mr. Hogg very shortly mentioned the geological divisions of that district; and, in pointing out the great extent of alluvial deposits and salt-marshes by the river Tees, as well as along its wide estuary, the many sand-links and limestone-cliffs on the sea-coast, he remarked that all these different formations were highly favourable for the *growth* of various plants. Whilst several rarer kinds had been lately *introduced* with ballast used in the making of the many railways, others, he regretted to say, had, after a lapse of many years, entirely *disappeared.*

Scientific and full descriptions of some of the more interesting varieties were necessarily reserved for a future communication.

Anagallis cærulea.
Antirrhinum elatine.
—— linaria.
—— minus.
Beta maritima.
Campanula hybrida.
—— rapunculus.
Cardamine amara.
Carduus acanthoides.
—— tenuiflorus.
Centaurea calcitrapa.
Chrysanthemum segetum.
Cichorium intybus.
Cuscuta epithymum.
Diplotaxis muralis.
—— tenuifolia.
Euonymus europæus.
Fumaria capreolata.
Galium mollugo.
Glaucium luteum.
Habenaria chlorantha.
—— viridis.
Hypericum hirsutum.
—— humifusum.
Knautia arvensis, *fl. albo.*
—— ——, *fl. pleno.*
Lepidium campestre.
—— ruderale.
Medicago sativa.
Melilotus leucantha.
Mercurialis annua.
Meum fœniculum.
Ononis arvensis, *fl. albo.*
Orchis pyramidalis.
Papaver rhœas, *fl. albo.*
Pastinaca sativa.
Phalaris canariensis.
Plantago major, *fl. pyramidali.*
Primula vulgaris, var. *caulescens.*
Prunus cerasus.
Pyrethrum parthenium.
Raphanus raphanistrum.
Reseda lutea.
Rosa rubella.
—— rubiginosa.
—— tomentosa, *fl. albo.*
Rubus fruticosus.
Salvia verbenaca.
Senecio sylvaticus.
—— viscosus.
Solanum nigrum.
Sorbus aucuparia.
Symphytum officinale.
Teesdalia nudicaulis.
Thalictrum flavum.
Trifolium incarnatum.
Verbascum thapsus.
Zostera marina.

Notes on Canadian Forests. By Dr. HULBURT.

This paper consisted of notes on the Canadian forests in connexion with climate

and contained a description of the varieties of vegetation within a district of about 2,000,000 square miles, extending from the Gulf of Mexico to the northern boundaries of Canada, and from the Atlantic Ocean to the western prairies.

Note on certain Influences regulating the Forms of Leaves, &c.
By MAXWELL T. MASTERS, *M.D., F.L.S.*

The object of this communication was, 1stly, to show the cause of the groove so generally met with on the upper surface of the leaf-stalk; and, 2ndly, to account for the oblique form of certain leaves.

With reference to the furrow on the leaf-stalk, it was shown that this is a provision to prevent undue pressure on the young growing leaf-bud, and at the same time to economize space. The truth of this notion is borne out by an examination of the leaf-bud, as well as by the fact that when, from various causes, no pressure is exerted, the leaf-stalk is not grooved, but cylindrical. A similar explanation may be given of the inner palea of grasses, which presents a central groove, into which the axis of the spikelet is received, and which is bounded by the two prominent ribs always present in that organ. In many *Restiaceæ* a similar provision exists against undue pressure: whenever, in these plants, a bract or scale is closely pressed up against the stem, that scale is provided with lateral ribs, bounding a central furrow, as in the upper palea of grasses; this scale, moreover, is frequently provided with a coating of hair, which affords additional protection against pressure. In other species, where no pressure is exerted, the scale is either entirely absent, or, if present, destitute of the lateral ribs and intermediate furrow. Similar illustrations may be found in the bracts of *Iris, Philydrum, Gladiolus,* and very many other plants. The obliquity of leaves was shown to be, in many instances, the result of a process of mutual accommodation, whereby one portion of a leaf is restricted in its growth by the nearness of a neighbouring leaf, while another part not so cramped for space grows to a proportionately greater extent—a process precisely resembling that which takes place in the outermost florets of some Crucifers, e. g. *Iberis,* the outer petals of some Umbellifers, &c. In the lime, the hazel, the mulberry, and many other plants, the leaves are oblique at the base, and the branch is bent away from the leaf at a considerable angle—is, in botanical language, flexuose; a space is thus left, which is filled up by the larger segment of the base of the leaf. Now, if a line be drawn across a lime leaf in such a direction as to cut off the projecting lobe at the base, it will be seen that this line is nearly parallel in direction to that part of the stem above the leaf in question, and from which it is deflected. The direction of this line is usually the same as that of the first or second lateral vein proceeding from the midrib towards the margin of the leaf, counting from the base of the leaf upwards. Several instances from natural as well as from exceptional leaves were adduced in support of the opinion just expressed; at the same time it was admitted that this explanation did not suffice to account for all cases of the kind, that of *Begonia* among others.

ZOOLOGY.

Descriptions of New British Polyzoa, with Remarks on some imperfectly known Species. *By* JOSHUA ALDER.

The species forming the subject of this communication belong chiefly to the branched calcareous forms of the genera *Cellepora* and *Eschara.* The new species described were named *Cellepora lævigata, Eschara ligulata,* and *Palmicellaria elegans,* the latter also a new genus, which is characterized as follows:—Polyzoary erect, calcareous, inarticulate, cylindrical, smooth, branching dichotomously. Cells disposed in four longitudinal, alternate series, those on the two opposite series being on the same level. Apertures circular, with a broad, projecting, palmate expansion in front, bearing an avicularium. This genus is proposed for a beautiful little coral dredged this year in Shetland by the Rev. A. M. Norman. The species remarked upon included the *Eschara lævis* of Fleming, a species lost sight of by British naturalists for many years; *Eschara Landsborovii,* now first ascertained to be an *Eschara,*

but the imperfect state of which had been described by Dr. Johnston as a *Lepralia* (this was found on the coast of Northumberland, by Mr. Embleton); *Quadricellaria gracilis* of Sars, previously published from an imperfect specimen under the name of *Onchopora borealis* by Professor Busk. *Scrupocellaria Delilii*, a species new to Britain, was got from the deep-water fishing-boats on the coast of Northumberland by Mr. Alder, and has since been dredged on the Durham coast. The last species described was the *Hornera borealis* of Busk, which is now introduced as British for the first time: specimens of this were got in Shetland by Mr. Barlee in 1858, and since by Mr. Norman. The paper was illustrated by drawings; and specimens of most of the species were exhibited.

On a New Species of Ione. *By* C. Spence Bate, *F.R.S.*

The genus *Ione* was first established by Col. Montagu, to receive a species of parasitic isopod Crustacea, allied to *Bopyrus*, which he found beneath the carapace of *Callianassa subterranea*, a variety of prawn that burrows beneath the sand, and is found at the entrance of Salcombe Estuary, as well as in Plymouth Sound. This prawn has likewise been taken on the coast of France, and the parasite described by Milne-Edwards. The new species, which the author has named *Ione cornutus*, was brought home by Mr. Lord, the naturalist to the Commission which had to determine the boundary-line between British territory and that of the United States, and was found parasitic upon a species of *Callianassa* which he took on the coast of Vancouver's Island. This species is much larger than that of the European form, and differs from it chiefly in having the lateral extremities of the somite, or segment which bears the antennæ, posteriorly produced upon each side of the head, after the manner of lateral horns. All the pereiopoda are short and powerfully subchelate. The branchial appendages are arborescent and pendulous; to the inner extremity of which two appendages are attached, each of which inversely increases as the other decreases; so that one is largest nearest the pereion of the animal, while the other is longest nearest the caudal extremity. To the posterior of these the male animal attaches itself by means of the seventh pair of pereiopoda. The author likewise remarked a very considerable variation in the form of the larvæ from that of either of the parents, although it more nearly corresponded with that of the male than with that of the female.

On the Syndactylous Condition of the Hand in Man and the Anthropoid Apes. By C. Carter Blake, *F.G.S., Hon.Sec.A.S.L.*

The author called the attention of the Section to a curious abnormity which is presented by the integument of a specimen of old male Gorilla which was brought from the Gaboon by Mr. Winwood Reade, and presented by that gentleman to the Museum of the Anthropological Society of London. The specimens of Gorilla which have been the subjects of the elaborate and complete memoirs which have appeared from the pen of MM. Duvernoy and Isidore Geoffroy St.-Hilaire in the Archives of the Paris Museum (vols. viii. and x.), and by Professor Owen in various parts of the 'Zoological Transactions,' have, with those described by other authors, all coincided in one attributed character, true as regards the specimens with which they were acquainted, which probably represent the majority of specimens of Gorilla which had been examined in Europe. This statement, reduced to a general proposition, was that the integument of the skin of the fingers was more or less connected across the first digital phalanx, in such a manner that the first joints were firmly connected together by skin, sometimes as far as the distal extremity of the first phalanx, sometimes merely to the middle of this phalanx. In no specimen of Gorilla, of the description of which the author is yet cognizant, are the digits of the anterior extremity free to the same extent as in man, in which the distal extremities of the metacarpals mark the termination of the amount of syndactyly of the hand. In the specimen of Gorilla to which allusion is made in this short note, the digits of the fingers present a different condition of connexion from that in the typical specimens described by zoologists. The second (index), third (medius), and fourth (annulus) digits are free beyond the distal end of the metacarpals, as in the human subject; the fifth digit (minimus) is also in a less degree attached to the annulus

than in the specimens of Gorilla contained in various public museums. We have thus a specimen of Gorilla in which the digits of the hand are almost as free as in the hand of the lower races of mankind. Careful examination, by a lens, of the integument, before the preparation of the specimen by Mr. Leadbeater, who first called the author's attention to this abnormity, demonstrates the fact that the epidermis covers the cutis on the inner sides of the interdigital spaces of the first phalanges of this specimen. The consistency of this epidermis merely differs in degree from that of the homologous structure in the foot and in other parts of the body. It would be interesting to compare such a curious abnormity of the integument with the similar abnormities which exist in the human species. The human fingers are most frequently connected together by syndactyly, and remain during life in that state of arrested development (as regards the integument) which is typified by the permanent stage of development of the Gorilla. On the other hand, the author has never yet met, either in the chimpanzee or orang-utan, with a similar case of freedom of digits to that here described. We must, however, recollect that the number of specimens of chimpanzee and orang-utan which have been accurately described anatomically forms a very small percentage. How many individuals of Gorilla may exist in which a similar "accidental" variety may exist, must remain for a long time unknown to us. The author then referred to cases of congenital syndactyly in man, and concluded by suggesting that the speculation whether a like rule, or its converse, may or may not prevail in the ape,—whether it might not through generations, during which the congenital defect of the Gorilla, or absence of the characteristic syndactyly, might be transmitted, operate towards the production of a more prehensile form of hand,—must be postponed until a larger series of specimens shall be examined by anthropologists or zoologists.

On the Marine Cyclopoid Entomostraca (Calanidæ), *with Notices of some Species new to Britain. By* George S. Brady.

Dr. Baird's 'Monograph of the British Entomostraca,' published by the Ray Society in 1849, and still the only authoritative work on the British species, contains descriptions of only three species of this family, viz. *Cetochilus septentrionalis*, *Anomalocera Patersonii*, and *Temora finmarchica*, the last of which seems to be involved in some obscurity. Mr. Lubbock has, however, since that date, given descriptions, in the 'Annals and Magazine of Natural History,' of several new British species. My own opportunities of observation have as yet been very limited. I have examined many gatherings, both littoral and from deep water, on the Northumberland and Durham coasts; and Mr. Norman has kindly placed in my hands some material of his own collecting, from the Shetlands and the Frith of Clyde. This, with the addition of a small gathering made by myself among the Channel Islands, constitutes the whole of the material which I have yet been able to obtain. It has yielded altogether nine species, four of which are new to Britain. It would be out of place here to enter into any minute descriptive details. The best specific characters will be found in the form and structure of the antennæ and the fifth pair of feet, and in the shape of the last abdominal segments: there are minor characters discernible also in other organs. One of the most curious points of structure is the strong serrated armature existing in many species on each side of the hinge-joint in the right antenna of the male.

I have compiled a table illustrating the distribution of the nine species which I have observed, but this can scarcely be thought of much value, owing to the want of copious gatherings from more distant places. It will be noticed that all the species have been taken in this district: we may be sure that equal opportunities of search in other places would have given a longer list. The four species referred to as being new to Britain are *Ichthyophorba hamata*, *Dias longiremis*, *Temora velox*, and a species of *Euchæta* (?) not yet determined. The most abundant species, both in the Shetland and Northumberland gatherings, and occurring plentifully also among the Channel Islands, was *Diaptomus longicaudatus*, Lubbock. This is especially abundant in the Northumberland district as a littoral species. I may also notice as being of common occurrence here and in Shetland *Evadne polyphemoides*, Leuckart, a species, I believe, hitherto unrecorded as British. Though found in com-

pany with the Cyclopoid species, it belongs to the family *Polyphemidæ*, and does not therefore come within the range of the present paper. *Temora finmarchica* is included in our list on the strength of one mutilated specimen which, however, agreed so well with Dr. Baird's figures as to leave little or no doubt about its identity.

	Northumb. & Durham.		Guernsey.	Clyde.	Shetland.
	Littoral.	Pelagic.			
Cetochilus septentrionalis, *Goodsir*	+	+	+	—	+
Anomalocera Patersonii, *Templeton*	—	+	—	—	—
Euchæta, sp.	+	+	+	—	+
Diaptomus longicaudatus, *Lubbock*	+	+	+	—	+
Pontellina brevicornis (?), *Lubbock*	—	+	+	—	—
Temora finmarchica, *Gunner*	—	+	—	—	—
„ velox, *Liljeborg*	+	—	—	+	—
Dias longiremis, *Liljeborg*	—	+	+	—	—
Ichthyophorba hamata, *Liljeborg*	—	+	+	—	+

On the Zoology of Hylton Dene, near Sunderland. *By* GEORGE S. BRADY.

Hylton Dene is a ravine or dell, through which flows a streamlet—in north-country phrase a burn—tributary to the river Wear, which it joins about a couple of miles above Sunderland Bridge. The burn itself is, like the Wear at that point, subject to tidal influence; but the adjacent pools of which we have to speak are above the level of high water at ordinary spring tides. On a flat expanse on each side of the burn are situated several small and very shallow pools, the depth of which is mostly only about six or eight inches. Zoologically we may divide them into three groups in the order of their proximity to the river Wear; and we find that the proportion of chlorides contained in their water regularly decreases as we recede from the river. As regards their organized inhabitants, the pools differ no less conspicuously than in their inorganic constituents. Those of the first and most saline group are marked chiefly by the presence during the autumn months of two Nudibranchs, *Alderia modesta* and *Limapontia depressa.* They contain also, in common with the second group, various Crustacea: *Gammarus locusta, Orchestia littorea, Palæmon varians, Crangon vulgaris, Corophium longicorne, Sphæroma*, sp., and *Temora velox*, an Entomostracan of the order Calanidæ. Besides these, there are two or three species of Foraminifera and some Annelids, I think of the genus *Nereis.* The second group is characterized more by the absence of certain species which occur in the first and third, than by any inhabitants peculiar to itself. The single large and deeper pool which forms our third group differs in nothing, except its peculiar Crustacean fauna, from an ordinary *freshwater* pond. It is of tolerable depth, but very narrow—more like a tortuous ditch than a pond; and it affords a home to numerous *Notonectæ,* Beetles, Water-rats, to a few individuals, small and stunted, of *Limnæus pereger*, and to a beautiful Polyzoon, *Plumatella repens.* The Entomostraca of this pool are all purely freshwater species, such as *Cyclops quadricornis, Candona lucens,* and several *Cyprides.* The most interesting inhabitants are, however, some of the larger Crustacea, *Palæmon varians, Mysis vulgaris,* and *Corophium longicorne,* all of which occur in great numbers.

Estuarine swamps, such as this, seem to be the nearest analogues we now possess of the extensive lagoons of the Carboniferous period. To the palæontologist it must be a matter of considerable interest to note the association of species in such localities; and I think enough has been said to show that considerable caution should be used in pronouncing upon the saline or freshwater nature of any deposits merely from the nature of the animal forms which they enclose.

Notes on Foraminifera new to the British Fauna.
By HENRY B. BRADY, *F.L.S.*

After some preliminary remarks on the various methods which have been proposed

for the separation of recent Foraminifera from bulky material, the author proceeds to enumerate and describe several species not before recorded as British, which, with some others not yet satisfactorily determined, had resulted from the examination of dredgings from various parts of our coast.

Experience showed that too great dependence should not be placed upon any single mode of treating foraminiferous sand; that, whilst difference of specific gravity might be taken advantage of, by floating and other means, for the separation of the more delicate forms, it was almost useless so far as concerned the porcellanous and arenaceous groups. In the manipulation of these the best assistance seemed to be derived from the use of wire-gauze sieves of different degrees of fineness.

The Shetland material, from which most of the specimens alluded to in the paper were derived, was dredged by Mr. J. Gwyn Jeffreys and Mr. E. Waller, at depths varying from 65 to 85 fathoms. That from the Irish Sea was from the Admiralty soundings, off Laxey, communicated by Mr. E. C. Davison, depth 15 fathoms. The sand from the Northumberland coast was taken from 35 fathoms, near Holy Island, during the recent dredging-operations conducted under the direction of the British Association Dredging Committee.

The following is a list of the species whose occurrence in the British seas is noted for the first time:—

Biloculina sphæra, *D'Orb.*	Shetland, very rare.
Biloculina contraria, *D'Orb.*	Shetland, very rare.
Triloculina tricarinata, *D'Orb.*	Shetland, very rare.
Quinqueloculina pulchella, *D'Orb.*	Shetland, only a single, somewhat monstrous specimen found.
Lituola scorpiurus, *Montfort.*	Shetland, rather rare.
Lagena distoma, *P. & J.*	Northumberland coast, rare; Shetland, very rare.
Glandulina lævigata, *D'Orb.*	Shetland, very rare.
Bigenerina digitata, *D'Orb.*	Shetland, rare.
Bolivina punctata, *D'Orb.*	Shetland, very small feeble specimens, not uncommon.
Planorbulina Ungeriana, *D'Orb.*	Shetland, common in some localities.
Planorbulina Haidingerii, *D'Orb.*	Shetland, rare.
Pulvinulina Menardii, *D'Orb.*	Irish Sea, rare.
Pulvinulina concentrica, *P. & J.*	Shetland, rare.
Pulvinulina Karsteni, *Reuss.*	Shetland, very small and delicate specimens, rare.
Rotalia orbicularis, *D'Orb.*	Irish Sea, rare; Shetland, rare.
Discorbina Bertheloti, *D'Orb.*	Shetland, rare.
Anomalina coronata, *P. & J.*	Shetland, common.
Polystomella crispa, var. arctica, *P. & J.*	Shetland, common.
Nonionina stelligera, *D'Orb.*	Shetland, rare.

On the principal Divisions of the Pacific Fauna. By W. Harper Pease, *of Honolulu. Communicated by* Dr. P. P. Carpenter.

The author, having been engaged for many years, personally and by his agents, in making careful explorations of the marine and land faunas of various groups of the Pacific islands, is preparing materials for a comprehensive work on the subject. He desires to correspond with other naturalists who are engaged in similar investigations.

He is led to the conclusion that the centre of creation for the Pacific fauna lay in the neighbourhood of the Philippines; one line of distribution passing in a northerly direction to the Hawaiian islands; another over the small islands near the equator; a third, through the larger groups, in a southerly line to the Paumatus and Marquesas.

The general elevation of land over the Pacific islands has been more regular than the tables heretofore made would lead us to believe.

The distribution of the land shells strangely coincides with that of the native races, the Papuan and the Malayan.

The Hawaian fauna is perhaps the most isolated in the world. The small islands still marked on the charts towards the American coast have no existence. But there is a chain of islands, running parallel with the axis of the Hawaian group, and connecting it with the northern part of Japan, which have been strangely neglected by the exploring expeditions. They have been principally examined by Capt. J. Paty, who was commissioned by the Hawaian government for that purpose. They are apparently in process of subsidence; but their shell-fauna coincides with the Hawaian.

On the Colour of the Salmon. By John Davy, *M.D., F.R.S.*

The colour, the subject of this paper, is that of the muscles of the Salmon and its congeners when in their highest condition—the peculiar salmon-colour. The author premises that it is commonly attributed to an oil. This conclusion he is not able to adopt, there being several facts opposed to it:—1st, that all the muscles are not similarly coloured, some even being colourless, as those of the eye, which are surrounded by and in the midst of a colourless adipose membrane; 2nd, that those muscles are not of highest colour, as the thin portion of the fish, which abound most in oil; 3rd, that the results of chemical examination tend to prove that the colour is not essential to the oil, but is seated in and belongs to the muscular portion, *i. e.* to those muscles which are most strongly coloured, such as constitute the thick part of the fish. The conclusion which, according to the author, seems most warranted by the facts, is that the colour depends on a peculiar colouring-matter of an organized kind, analogous to those colouring-matters which exist in plants, especially their leaves and flowers, and in the tegumentary parts of mammalia, birds, and fishes, such as the hair of the first, the feathers of the second, and the epidermis of the third. And in accordance, he thinks, it may be a secretion, partly depending on the food taken, such as is required to bring the fish into its highest condition.

List of the British Pycnogonoidea, with Descriptions of several New Species. By George Hodge.

No complete list of the British Pycnogons has appeared, and such information as we possess is scanty and scattered. It is difficult to account for this neglect, as these animals possess considerable interest both in their life-history and their peculiarly degraded physiological features.

An examination of such records as I have been able to consult has enabled me to compile a list of twenty-two species, the total number recorded as British. With two exceptions, that of a *Phoxichilidium* by Mr. Gosse and a *Phoxichilidium* and a *Nymphon* by myself, no new species have been published since Harry Goodsir and Dr. Johnstone's time: the former described seven species, principally from the Frith of Forth; it is possible, however, that two or three of them might not stand a very critical examination.

The list, as it now stands, contains

13	species of	Nymphon,
2	„	Pallene,
4	„	Phoxichilidium,
1	„	Pasithoë,
1	„	Phoxichilus,
1	„	Pycnogonum;
22		

in all twenty-two species, including the four which were recorded in my Report of the Pycnogons obtained last year during the dredging-expedition to the Dogger Bank under the auspices of this Association.

I have now to increase this list by the addition of ten species, seven of which are new to science, and three new to Britain.

The new species are contained in the following genera:—

Ammothoa, a genus not before represented by any British form.
Achelia, a new genus which I found it necessary to establish.
Pallene and *Phoxichilidium*.

The genus *Ammothoa* is in some respects like *Nymphon*, the most decided difference being the greater number of joints of the palpi, *Ammothoa* possessing eight, whilst *Nymphon* has only five. The foot-jaws in *Nymphon* are always as long or longer than the rostrum; in *Ammothoa* they are much shorter.

I have two new species to describe, for which the specific names of *brevipes* and *longipes* are proposed.

The limbs of *Ammothoa brevipes* are short and robust, furnished with moderately long, strong spines. The rostrum is conical, with the apex truncate; the foot-jaws nearly two-thirds the length of the rostrum; palpi equal in thickness throughout,—if anything, slightly thicker at the free end. Oculiferous tubercle terminating in a pointed wart, directed backwards. Abdomen long, slightly tapering.

Several specimens have occurred on the Durham coast, from deep water.

Ammothoa longipes is more slender in general form than *Ammothoa brevipes*. The rostrum is as long as the thorax, tapering to a moderately blunt point. The palpi are long and slender, the four terminal joints being of about equal length.

A single specimen from Polperro.

Achelia is distinguished by the possession of two pairs of palpi, one pair long and slender, the other short and stout. The genus may be thus characterized:—

> Antennæ two-branched, one pair long and slender, eight-jointed, the other pair short and stout, two-jointed, and produced immediately in front of the oculiferous tubercle.

In some respects this genus agrees with a form possessing two pairs of palpi, which Kröyer named *Zetes*; it may, however, at once be distinguished by the very different character of the rostrum, *Zetes* being much elongated and seated upon a sort of stalk, *Achelia* being short and stout.

I have three species of this genus to describe, for which the specific names of *echinata*, *hispida*, and *lævis* are proposed.

Achelia echinata is robust, with moderately long legs, furnished with strong spines produced from little eminences upon the limbs and body. The oculiferous tubercle is directed forwards, and terminates in a little point, directed backwards. The inner palpi are of the same length as the oculiferous tubercle, the outer being longer than the rostrum. The colour is a fine sienna to a pale straw.

This species has been found in the Channel Islands, the Isle of Man, and upon the Durham coast. It is by no means uncommon, from low tide to a few fathoms.

Achelia hispida is distinguished from *Achelia echinata* by the much smaller dimensions of the spines, which, in this species, are mere hairs, and also by the relative sizes of the inner palpi and oculiferous tubercle; the latter organ reaches but a little beyond the origin of the inner palpi, which are robust and furnished with two circlets of little spines ranged round the upper and lower ends of the first joint.

Achelia lævis is remarkably free from hairs, merely possessing a few small ones on the femoral and tarsal joints. The oculiferous tubercle is much shorter than either of the preceding, the inner palpi more closely resembling those of *Achelia echinata*.

The two latter species were sent me from Polperro, in Cornwall.

The rostrum of *Phoxichilidium virescens* is stout, slightly thickened in the middle, truncate at the apex. The foot-jaws are slender and closely approximated at their origin, each finger with 6–8 teeth. Legs moderately long. Colour pea-green.

Several specimens of this species were sent me from Polperro.

At first sight it might be mistaken for *Phoxichilidium olivaceum*, but the closely approximated foot-jaws at once show its distinct character.

Pallene pygmæa was taken by Mr. Spence Bate so far back as 1853, and by him noticed in a paper of that year read before this Association at Hull. It was, however, neither named nor described, his remarks bearing upon the larval stages of these animals. I have also taken a single specimen upon the Durham coast; it may be thus characterized—

> Thorax robust; legs long and slender, constricted at the joints; last joint falciform, with a strong toothed shoulder at the base. Two strong spines on the sixth joint. Rostrum short, stout. Foot-jaws closely approximated. Oculiferous tubercle moderately long. Abdomen stout.

The three species new to Britain all belong to the genus *Nymphon*. They were described by Kröyer in Gaimard's 'Scandinavian Voyage.' One species, *Nymphon*

Strömii, has been taken in Shetland by the Rev. A. M. Norman; the other two, viz. *Nymphon mixtum* and *Nymphon longitarse*, have been taken by myself on the Durham coast.

The following list contains all the species at present known to inhabit the British seas:—

Nymphon, *Fabricius.*
- gracile, *Leach.*
- grossipes, *Fabricius.*
- femoratum, *Leach.*
- pictum.
- giganteum, *Johnston.*
- longitarse, *Kröyer.*
- mixtum, *Kröyer.*
- Strömii, *Kröyer.*
- hirtum, *Fabricius.*
- brevitarse, *Kröyer.*
- Johnstoni, *Goodsir.*
- spinosum, *Goodsir.*
- pellucidum, *Goodsir.*
- simile, *Goodsir.*
- minutum, *Goodsir.*
- brevirostre, *Hodge.*

Ammothoa, *Dana.*
- brevipes, *Hodge.*
- longipes, *Hodge.*

Achelia, *Hodge.*
- echinata, *Hodge.*
- hispida, *Hodge.*
- lævis, *Hodge.*

Pallene, *Johnston.*
- brevirostris, *Johnston.*
- circularis, *Goodsir.*
- pygmæa, *Hodge.*

Phoxichilidium, *M.-Edwards.*
- coccineum, *Johnston.*
- globosum, *Goodsir.*
- olivaceum, *Gosse.*
- petiolatum, *Kröyer* (Pallene attenuata, *Hodge*).
- virescens, *Hodge.*

Pasithoë, *Goodsir.*
- vesiculosa, *Goodsir.*

Phoxichilus, *Montagu.*
- spinosus, *Latreille.*

Pycnogonum, *Fabricius.*
- littorale, *Ström.*

There can be little doubt that a careful examination of the species found on various parts of our coast would add many new forms to this list, especially amongst the smaller species.

Whilst most departments of marine zoology have made rapid strides within the last few years, our knowledge of the Pycnogons has scarcely advanced. No doubt this is owing in a great measure to the difficulty in determining the species in consequence of there being no complete list. It is hoped the foregoing may in some degree supply this want, and lead to these animals being better known and understood.

On the Roman Imperial and Crested Eagles.
By John Hogg, *M.A., F.R.S., L.S., &c.*

The author, in giving an account of the Roman Imperial Eagle and several *crested* or *crowned* Eagles, showed that the former bird is the *Aquila heliaca* of Savigny, which, in many of its characters, resembles our Golden Eagle (*A. chrysaëtus*).

The Roman Eagle was *not* crested; and when lately engaged on his Memoir on Baalbec, the author was led to inquire if any existing species of the Eagle tribe could really have been the type of the beautifully sculptured *crested* Eagles which are seen in the Temples of the Sun at Baalbec and at Palmyra, in Syria.

The author then described several *crested* or *crowned* Eagles, two of which are natives of Africa, viz. *Aquila Desmursii* and *Spizaëtus coronatus*; and these, with the Crested Indian Eagle, *Spizaëtus cirrhatus*, inhabiting Nepal and India, might have been known to the Roman artist, and so have been taken for the model of those sculptured birds. He further described the *Thrasaëtus harpia*, furnished with a larger *crest*, as well as that noble bird recently added to the Eagle-collection in the Zoological Society's Gardens in the Regent's Park, the *Harpyhaliaëtus coronatus* of Temminck; but since both these species are natives of South America, they could not have influenced the sculptors in their selections of a type. Hence it is probable that one or both of the African birds might have afforded to the Roman artists, suggestions for the modelling of the *crested* Eagles, which are so well executed in the temples of those ancient cities.

Mr. Hogg illustrated his descriptions with several drawings which he had made of those sculptured Eagles, and of some of the species under consideration.

An Account of the Attempts to Transport Salmon to Australia. *By* T. Johnson.

The apparatus employed in the different attempts to carry out the ova and fry were exhibited. The author showed specimens of fry hatched from ova which had been buried for ninety days in the Wenham Lake Ice Company's Wells. In the same vessel were placed for comparison fish from the same ova, but which have been hatched in the ordinary way: these were considerably larger than those produced from the preserved ova.

Note on some Foraminifera dredged by the late Mr. Lucas Barrett at Jamaica. *By* Professor T. Rupert Jones, *F.G.S.*, *and* W. K. Parker.

Of these specimens (evidently only the larger and more conspicuous members of a rich Rhizopodal fauna), some were taken at from fifteen to twenty fathoms, namely, *Quinqueloculina agglutinans*, *Q. pulchella*, *Orbiculina compressa*, and *O. adunca*; some at from 50 to 100 fathoms, namely, *Orbiculina compressa*, *Dentalina acicula*, and *Orbitolina vesicularis*; and several others at from 100 to 200 fathoms, namely, *Dentalina acicula*, *D. communis*, *Cristellaria rotulata*, *C. cultrata*, *C. calcar*, *Frondicularia complanata*, *Amphistegina vulgaris*, *Polytrema miniacea*, *Bigenerina nodosaria*, *Verneuilina tricarinata*, *Textularia trochus*, *T. Barrettii*, *Cuneolina pavonia*, *Lituola scorpiurus*, and *L. Soldanii*.

Cuneolina, a rare form, hitherto known only by figures and descriptions given by D'Orbigny, proves (as suspected) to be a modification of *Textularia*; and *T. Barrettii* is intermediate between it and *Textularia* proper. The *Frondiculariæ* are remarkably large and beautiful; and the *Cristellariæ* and *Dentalinæ* are also large and relatively abundant.

This fauna is almost identical with the fossil Foraminifera of the *Pteropod-marl* of Jamaica, a tertiary stratum, specimens from which were also given by the late Mr. Lucas Barrett in 1862 to the authors of this notice.

Abstract of the Report of a three-weeks' Dredging-Cruise off Scarborough. *By* J. Leckenby.

The author described the nature of the ground upon the Dogger Bank, distant about 70 miles from land—rough gravel (northern drift) with fragments of jasper, greenstone-porphyry, &c., similar to those which strew the beach near Scarborough, and the purely littoral character of the Dogger fauna; the depth of water on the bank ranging from 5 to 15 fathoms, the sea often breaking over the shallower parts.

He further described the results of dredgings in deep water in apparently lias mud, 40 to 50 miles from land, between the Dogger Bank and the coast. Amongst others of less note were obtained—

Fusus Turtoni,	Scalaria Trevelyana,
—— norvegicus,	Bulla Cranchii,
—— ? ovum,	Crenella nigra (very large and fine),
—— propinquus (abundant),	Nucula tenuis,
Mangelia nebula,	Leda caudata (very large),
Natica Montagui (very large and fine),	Syndosmya prismatica (very large),
—— grœnlandica,	Solen pellucidus, $1\frac{3}{4}$ in. in length,

many of the species enumerated not having been hitherto obtained by the dredge.

He also gave a list of species obtained within 10 miles of the shore, at a depth of from 20 to 25 fathoms, and enumerated the various Echinoderms that were obtained, and recorded the occurrence amongst the Crustacea of *Pagurus cuanensis*, hitherto only found off the Irish coast.

On the Irruption of Syrrhaptes paradoxus. *By* A. Newton, *F.L.S.*

These birds, which are commonly known as Pallas's Sand-grouse, and which are of Chinese origin, have made recent visits to this country, but have been rapidly exterminated or driven away. It appeared from the statement of the paper, that about 109 of these rare birds had been killed in the British Isles, of which 63 were shot in Norfolk and Suffolk. The author strongly condemned the unnecessary

slaughter which had taken place, and was still taking place, among this species, which would have established itself here if it had received the commonest hospitality.

On the Morphology of the Ophiuroidea. By the Rev. Alfred Merle Norman.

The structure of the skeleton in these star-fishes was commented upon with especial reference to certain morphological points which were found to be of great value in the elucidation of species, but which had not hitherto been attended to by British naturalists. The following recent additions to our fauna were mentioned:—*Ophiura Sarsii* (Lütken), *Ophiura squamosa* (Lütken), *Ophiura affinis* (Lütken) (synonymous with *O. Normani*, Hodge), *Amphiura Chiajii* (Forbes), *Ophiopeltis securigera* (Duben and Koren), *Asteronyx Loveni* (M. and T.); and the specific characters of the several forms were pointed out.

On British Holothuriadæ with reference to new Species. By the Rev. A. M. Norman.

The object of this paper was to bring together information which is scattered through many publications on the naked Echinodermata of Great Britain. Since the publication of the late Professor Forbes's work, several species of interest have been added to our fauna—namely, *Cucumaria elongata* (Duben and Koren), *Thyone raphanus* (Duben and Koren), *Psolus squamata* (Duben and Koren), *Holothuria nigra* (Peach), and *Synapta inhærens* (Müller). The author described three new species: *Psolinus pusillus*, taken by Mr. Alder and Mr. G. Hodge on the coast of Durham; *Thyone floccosa*, from Cornwall; and *Synapta tenera*, dredged by Mr. D. Robertson in the Clyde district. Attention was especially called to the value of the examination of the dermal spicula or calcareous plates in determining specific character in this order. These plates are generally profusely distributed in the skin of the Holothuroidea, and are also found in the feet and tentacles.

On the Occurrence of the Sperm Whale (Physeter macrocephalus) *near Wick, N. B. By* C. W. Peach.

It was found floating dead on the west side of this county (Caithness) in August 1863, and towed into a small cove near Reay. Its length was between 60 and 70 feet, and it yielded about 1620 gallons of blubber, spermaceti, and oil. Each lower jaw had about 22 teeth.

Captain Macdonald, of Sandside House, purchased it of the Receiver of Wreck, and under his superintendence the skeleton has been carefully preserved. The authorities of the British Museum have since purchased it for that institution.

Notice of a Monstrosity in a Whiting. By C. W. Rose.

The fish, which was exhibited to the Section, had three eyes, two in their natural position, and one between the two. He believed *lusus naturæ* among fish very rare, a great authority upon the subject mentioning only two such malformations —in one case a contraction of the upper jaw, and in the other an elongation of the lower. As a proof of the rarity of these occurrences, it was only necessary to bear in mind that, amongst the thousands of whiting brought in, and the hundreds of thousands of mackerel and herring, this was the only instance of the kind of which there was any note.

On the Generic Characters furnished by the different Modes of mining Leaves adopted by the Larvæ of Micro-Lepidoptera. By H. T. Stainton.

There are no less than 20 different genera of the *Tineina* of which the larvæ mine beneath the skins of the leaves of plants; some of these always remain miners, having no power of quitting their mine to enter a fresh one; some even change to the pupa state within the mine, but the greater number issue from their mines when full-fed, some before doing so cut out flat oval cases from

the mined portion of the leaf, in which they descend to the ground, and therein change to the pupa state. Some mining larvæ move freely from one leaf to another; some only mine when they are young, feeding externally when about half-grown. Some of these mining larvæ have the usual complement of legs and prolegs; some have only 8 prolegs, the first pair of ventral prolegs being absent; finally, some are entirely without legs, and these are difficult to recognize as Lepidopterous larvæ.

On some Elucidations of the Geological History of North Africa, supplied by its lacustrine Fauna. By the Rev. H. B. Tristram.

On certain Facts on the Variation of Species, which point to Western Asia as the centre of Creation for the Palæarctic Region. By the Rev. H. B. Tristram.

On the Physical Geography of the Malay Archipelago. By Alfred R. Wallace.

This archipelago extends from the Nicobars on the north-west to San Cristoval, one of the Solomon Islands, on the south-east; and from Luzon, on the north, to Rotti, at the south-west angle of Timor, on the south; being an irregularly triangular area of 29½° latitude, by 69° of longitude. For ethnological and other purposes the Malay peninsula, though a portion of the mainland, is included in this insular belt; and analogous reasons induced the determination of the eastern limit. The author advocated the insertion in all future atlases of a special map of these islands, comprising so many races of man and such variety of physical phenomena as to entitle it almost to be regarded as the sixth great division of the globe. The immense number of active and distinct volcanos were then mentioned (the islands in which the former occur being unusually liable to earthquakes), as also the immense forests which, throughout a great portion of the archipelago, clothe even the loftiest mountains to their summits; while in other portions these give place to arid hills and plains scantily covered with scrub. The meteorological phenomena display similar contrasts, some of the islands experiencing the monsoons with the utmost regularity, while others show an inconstancy of climate resembling our own. But the most marked feature of the physical geography of the region is to be found in the fact that one large section is connected by a very shallow sea with the continent of Asia, while a similar submarine plateau unites another portion to Australia; the intervening belt of ocean being almost unfathomable.

The author then subdivided the islands into—1. Volcanic and Non-volcanic; 2. Forest Country and Open Country; 3. Well-marked Seasons and Undefined Seasons; and 4. Western or Indo-Malayan Region, and Eastern or Austro-Malayan Region.

As to the first, Borneo and Celebes formed two central masses, round which the volcanic islands are distributed in a band about 5000 miles in length, roughly conforming to their outline, and comprising about fifty active volcanos. Throughout this entire length are to be found, at innumerable points, most convincing evidences of frequent upheavals and depressions of land, especially of upraised coral-reef. The island of Celebes, the great mass of Borneo, and the whole Malay peninsula have absolutely no volcano, active or extinct; and there is a similar quiescent area, 1000 miles wide, in the great island of New Guinea, where no volcano is known to exist nor earthquake to occur in an island estimated to contain 290,000 square miles, or 53,000 more than Borneo, hitherto regarded as, after Australia, the largest island in the world. Still further to the east occur a few small active volcanos.

After describing the most striking peculiarities of climate and seasons, the author passed to the consideration of the geological formations and zoological products, and stated as a recognized fact that one portion of the archipelago is entirely Asiatic, while the remaining portion is quite as distinctly Australian. In support of this view, he briefly discussed the relations of the geographical distribution of animals and plants with geology; and claimed that the same changes in geological distribution of land and water, of which we have so many evidences in our present acquaintance with the constituents of the earth's crust, are still going on.

Wherever upon islands contiguous to each other or to a continent animals or plants of the same or closely analogous descriptions are observed, it will be found, upon investigation, that the sea between them is shallow; and that where a deep sea divides islands from each other, there entirely different types will be found. An upheaval of only 50 fathoms would make dry land of the whole sea intervening between Borneo, Java, and Sumatra, and the mainland of Malacca and Siam, while the 100-fathom line of soundings includes the Philippines and other groups; from which fact he argues the comparatively recent submergence of this part of Asia. He then adduced a variety of arguments from the zoological world, instancing examples both of Carnivora and Ruminantia which are common to the islands named and to Southern Asia, while they are totally unknown to Australia, yet which could never have reached the islands of the western section from the mainland of Asia so long as the ocean retained its present configuration.

A few anomalies are observable in the Philippines, which could sufficiently be accounted for by the more remote period at which they were cut off from Asia, as indicated by the greater depth of the intervening ocean. The islands, from Celebes and Lombok eastward, present many of the characteristic features of the Australian region, as indicated by the shallow sea and the similarity of fauna and flora between the eastern section of the Indo-Australian archipelago and Australia, while the strait, barely 15 miles wide, between Bali and Lombok, marks the dividing-line between the Asian and Australian kingdoms of natural history. From these various data a general conclusion may be drawn, that all the islands eastward of Borneo and Java formed part of an Australian or Pacific continent, from which they were separated at a period not merely long antecedent to the submergence of the adjacent portion of the Asiatic continent, but probably long before any portion of South-eastern Asia emerged from the waves; basing this conclusion upon the comparatively recent geological formation of Java and Borneo, and on the great depth of the sea between Borneo and the eastern section of the archipelago, which pointed to a very long period during which the two continents of Asia and Australia were widely separated.

Particular attention was called to the fact that the division of the archipelago now pointed out did *not* correspond to any physical or climatal divisions; for the volcanic band runs through both sections, and the climates of Borneo and New Guinea are very similar; yet in spite of these, which are usually deemed the necessary conditions for ensuring similarity of animal life, the most striking contrast between them respectively at once forces itself even upon the most unobservant traveller. The difference between these two sections of the archipelago was further illustrated by showing what would be the consequence of the two continents of Africa and South America becoming joined in the course of ages by the slow upheaval of the Atlantic bed, and the erosive agency of rivers on either continent. If, then, a renewed period of upheavals occurred, islands would have been formed similar to those of the Indo-Australian archipelago, yet equally dissimilar as to natural history. The paper concluded by urging upon naturalists increased devotion to that science, as tending to throw light upon many of the most recondite questions of the earth's previous history.

On the Geographical Distribution of Animal Life. *By* A. R. Wallace.

The author called attention to the six geographical regions established by Dr. Sclater (Proc. Linn. Soc., Feb. 1858) for ornithology—viz., 1st, the Neotropical, comprising South America and the West Indies; 2nd, the Nearctic, including the rest of North America; 3rd, the Palæarctic, composed of Europe, Northern Asia to Japan, and Africa, north of the Desert; 4th, the Ethiopian, which contains the rest of Africa and Madagascar; 5th, the Indian, containing Southern Asia and the western half of the Malay archipelago; and 6th, the Australian, which comprised the eastern half of the Malay Islands, Australia, and most of the Pacific Islands. It was stated that these regions would apply almost equally well to mammalia, reptiles, land-shells, and insects; but there were some exceptional cases, which it had been thought would render these regions inapplicable to zoology generally. These exceptional cases were—1st, that the batrachians of Japan are Palæarctic, agreeing with the birds, &c.; but the snakes are altogether Indian, as

pointed out by Dr. Günther in his paper on the geographical distribution of reptiles (Proc. Zool. Soc. 1858, p. 373); 2nd, that the mammalia of North Africa are not European, like the birds; 3rd, that the insects of the Moluccas and New Guinea are generally of Indian forms, while the birds and mammals are Australian; and, 4th, that the insects of Chili are of North-Temperate and Australian forms, while the birds and mammals are mostly of true South-American groups. These cases were treated successively; and it was shown that the statement as to the mammals of North Africa was incorrect, and that they really very strongly confirmed the evidence of the birds and reptiles as to that country being Palæarctic. In the other cases the anomalies of distribution were explained as being due to special exceptional circumstances, which should not invalidate the general accuracy and usefulness of these divisions. The discrepancies in the distribution of plants, which, while often agreeing with those of insects, were much greater, were supposed to be in a great measure due to the adventitious action of the glacial epoch and of floating ice. In conclusion, naturalists were called upon to furnish detailed information as to the agreement or discrepancies of this system of geographical regions in the groups to which they paid special attention, so that a final conclusion might be arrived at as to the advisability of adopting them for general use.

Physiology.

Address by Professor Rolleston, *F.R.S., President of the Subsection.*

The President opened the business of the Subsection by a bibliographical survey of recent physiological works, periodical and systematic. Speaking, firstly, of British periodicals, he observed that the liberality of our various scientific societies in publishing so many volumes of Proceedings in octavo, with illustrations, accounted for the more or less popular character of most other English scientific journals. More strictly and severely scientific papers were to be found on the Continent, in such works as the 'Zeitschrift,' published under the auspices of Siebold and Kölliker, or the 'Archiv' of Reichert and Du Bois Reymond, than we ordinarily saw in publications devoted similarly to biological science, and dependent similarly on public patronage, in Great Britain. The rapidity and readiness with which the societies alluded to published the most rigidly scientific dissertations made them, within these islands, the favourite channel for such communications. On the other hand, the fact that a large number of semi-scientific natural-history periodicals were published in this country proved that a strong taste for such subjects was becoming widely diffused throughout it.

The more exclusively professional and practical medical press gave evidence of a similar tendency in the important section of the community for which it was intended, by the publication of lengthy series of lectures on the more recondite parts of philosophical anatomy, which could scarcely have any very direct bearing on the practical exercise of the art of healing.

Passing from periodical to systematic literature, Professor Rolleston said that there were three great departments, viz. that of experimental physiology, that of structural and especially of microscopic anatomy, and, thirdly, that of comparative anatomy, in which accessions both to our knowledge and to our means of obtaining it, had been recently made. In the department of experimental physiology, Dr. Edward Smith's, Dr. Davy's, Dr. Radcliffe's, and Dr. Pavy's recent works were well known to the Members of the Association, before whom the authors had brought, or would upon the present occasion bring, papers. Whilst upon this subject, Professor Rolleston made some remarks upon vivisection. A defence might be set up for it upon the following grounds, and under the following limitations:—Firstly, in the operations passing under that name, the first thing done in many cases was to extinguish life and sensibility in a manner (as by pithing) as much more speedy than the ordinary methods for the destruction of animals, as the scalpel of the anatomist was a surer and speedier agent than the clumsy tools of the slaughter-house or the uncertain ones of the sportsman. In

such cases, the term vivisection was a misnomer. Secondly, chloroform was in these days almost invariably employable and employed: the cases in which it could not be put into use, on account of its introducing some chemical or other source of fallacy, were very few. On the other hand, it was quite open to the opponents of vivisection to say, that recognizing the susceptibility to pain which the lower creatures had, and, in addition to this, certain rudiments in them of a moral nature, as giving them still further claims upon our consideration, and feeling that we could not without grievous injury to our own better nature make a practice of sacrificing their lives, we were necessitated to regard vivisection as something unjustifiable and indefensible. To this it might be replied, that such a line of argument, if consistently followed out, would lead, as indeed it had led, to vegetarianism, against which the instincts and, even less ambiguously, the practice of the great mass of mankind would be found to rebel, at all events at present. And it might further be said, that the results of experiments on the lower animals had enabled us to understand something of the nature of, and to combat, with something of success, the attacks of two terrible human maladies, epilepsy and diabetes. The question was a complex one, very different considerations having to be weighed one against the other, one scale containing human, the other brute suffering. Wantonness and malignity were, of course, excluded from our consideration; whilst, on the other hand, the means at our disposal for the extinction of sensibility and of life diminished the amount of brute suffering to a very small actual residue. Nothing, however, could be alleged in favour of vivisection, if practised for the sake of obtaining merely greater operative dexterity; and the whole discussion was expressly limited to the consideration of it, as practised in England, by the following words:—"In a country like this, where human life is highly prized, brute misery will never be wantonly produced: 'The merciful man is merciful unto his beast.' It is possible that, where human life is held cheap, the man who loveth not his brother may be wanton in his treatment of the brute. This is not the case here, and in a British Association I need allude no further to the matter."

In structural (and especially in the microscopic part of structural) anatomy, the writings of Professors Beale and Kühne (both of whom had read papers last year before the Subsection) were particularly noteworthy, and the names of Dr. Turner and Dr. Roberts were both honourably connected with the subject and with the Association. As a periodical, the 'Quarterly Journal of the Microscopical Society,' and as a systematic work, Virchow's 'Cellular Pathology,' were deserving of our best acknowledgments.

The important questions of "Man's place in Nature," and of the relative position of the several varieties of the species, had never received so much attention from professed anatomists as within the present year. Professor Huxley's name at home, and Karl Vogt's abroad, sufficiently illustrated this observation; and Von Baer and Rudolph Wagner were devoting the evening of their long lives of successful biological labour to the elucidation and exposition of this momentous question.

The most recent systematic work on comparative anatomy with which the speaker was acquainted was that of Gegenbaur's, and it was also a most excellent one; and Professor Owen's edition of Hunter's 'Essays and Observations' was a most valuable addition to the literature of that branch of knowledge.

No place could boast of better workers in zoological anatomy than Newcastle, rich in an Albany Hancock, a Joshua Alder, a Dr. Embleton; nor could any local natural-history society fairly claim a superiority over the Tyneside Naturalists' Field-Club.

A new systematic work on zoology was now issuing from the Leipsic press: the names of the several authors, Peters, Gerstäcker, and V. Carus, were a very abundant guarantee for its anatomical and physiological merits.

The present was a period preeminently fruitful in systematic treatises on physiology. The excellent English manual, by Dr. Kirkes, had just reached its fifth edition; one, if not both, of Dr. Carpenter's larger works were out of print, and would, it might be expected, shortly reappear in fresh editions. On the Continent, Funke's very comprehensive 'Lehrbuch' was passing through its fourth, Vierordt's had attained its second, and Budge's within the present year its eighth edition.

The remainder of the Address consisted of considerations, firstly, of the general usefulness and, secondly, of the educational value and applicability of the natural-history sciences.

On the Ventilation of Barracks and other Public Buildings in India. By STEWART CLARK, *Inspector-General of Prisons in the North-west Provinces.*

All the barracks recently erected in India are well supplied with means for natural ventilation; still, when occupied by the regulation number of men, the air during night-time is very impure. It has been shown that, in a tropical climate, natural ventilation will not proceed during certain atmospheric conditions; and however well any apartment may be supplied with doors, windows, &c., no movement of the internal air sufficient to change the atmosphere will take place. Therefore ventilation by artificial means must be resorted to; otherwise the inmates must suffer. It is evident that, on account of the climate, the peculiar construction of suitable buildings renders ventilation by heat or vacuum impracticable, and therefore the "plenum" is the only method by which the ventilation under consideration can be accomplished. Fresh air forced into an apartment may not, it is true, completely expel the foul; but if openings for the ingress of the air be judiciously arranged, the greater part of it will be got rid of by the open doors and ventilators, and what remains will be so completely diluted that no harm will come of inhaling it. An ordinary blower, $4' \ 9'' \times 2' \ 6''$, constructed on the eccentric principle, with a revolving fan $3' \ 9'' \times 2' \ 5''$, and worked by manual labour, will discharge (allowing even a broad margin for laziness on the part of the driver) 4000 cubic feet of air per minute, and will throw into two apartments $70' \times 20'$ each, through forty suitably arranged openings, upwards of 2000 cubic feet of air per minute, being at the rate of more than double the quantity (estimated at 20 cubic feet per minute) generally considered necessary for the complete removal of putrescent matters from soldiers' dormitories. A number of plates accompanying the paper exhibited the plan of a barrack $70' \times 20'$, arranged with twenty beds, ventilated by forced ventilation, with sections and elevations of the whole apparatus, which the author had reason to believe was well adapted to the ventilation of soldiers' barracks and other public buildings in hot climates. The whole apparatus is of the most simple kind: it can be erected and kept in perfect working order by any ordinary joiner. The apparatus now in use at the Agra Prison was erected entirely by the prisoners. The first one was constructed for a corridor of sixty-eight cells, and cost about £24 (240 rupees), including the cost of convict labour at the usual rates. Eight men are required to work each blower during twenty-four hours. Supposing the apparatus adjusted for two barracks, each arranged for twenty beds, so that the same blower will do for both, and cost at the usual contract rates £50 (500 rupees), or £1 5*s.* (12 rupees 6 a.) per soldier for plant—the cost of working per mensem at 7*s.* (3 rupees 8 a.) per coolie being £2 16*s.*, or 28 rupees—the total cost per annum for each soldier, including wear and tear, &c., would not exceed £1, or 10 rupees. This will be admitted to be no large outlay for the benefits of good ventilation. Such an outlay, calculated on the aggregate of the European force in India, would amount to a very large item; but supposing that good ventilation would prevent at least one-half of the frightful sickness and mortality that take place in the Indian army, which he believed it would do, the balance-sheet at the end of the year would be in favour of improved ventilation, independently of the increased efficiency of the soldiers and of the army generally.

On the Ligamentous Action of the Long Muscles in Man and other Animals. *By* DR. CLELAND.

The author pointed out that, in the human subject, maximum flexion of the hip-joint could not be obtained along with full extension of the knee, on account of the shortness of the hamstring muscles; and so also maximum flexion of the ankle-joint, along with full extension of the knee, was prevented by the shortness of the gastrocnemius muscle. This limitation of movements by the shortness of muscles, he said, was best seen in the humeral region of the horse, where it was so great that very little flexion or extension of the shoulder could occur without a corresponding movement

at the elbow; well-marked instances of similar interdependence of joints were to be found in other parts of the horse, and also in other animals—*e. g.* in the legs and wings of birds. He proceeded to show that movements of that description in the humeral region of the horse were exactly those most frequently and usefully employed by human beings; that the shoulder and elbow were usually flexed and extended together; that likewise in walking, leaping, &c., flexion and extension of the hip, knee, and ankle went together; that in those movements the long muscles were not alternately contracted and extended, but kept in a state of medium contraction, very slightly altering their length, and were, therefore, evidently not the muscles which produced those movements. On the other hand, it was shown that a muscle passing over two joints, if maintaining a definite length, would cause another muscle passing over only one of them to act upon both. It was argued that, in the movements referred to, the long muscles gave force, but not velocity.

Note on the Change of Attitude which takes place in Infants beginning to Walk. By Dr. Cleland.

This paper was illustrative of two drawings traced from a mesial section of the body of a newly born child. One of the drawings showed the position of the vertebral column when the head was bent forwards, and the thighs flexed upon the body; the other its position when the body was stretched straight with the thighs in a line with the trunk. It was shown that the vertebral column of the newly born child was capable of being curved in any direction in its extent above the sacrum, but that the sacral concavity forwards was already formed. The limbs, however, could only be made to lie in a straight line with the trunk by bending the pelvis back, so as to develope the lumbar convexity forwards of the column. Thus the straightening of the limbs when the child begins to walk was shown to be effected not by mere motion of the hip-joint, but by development of the lumbar convexity of the vertebral column. In the drawing of the stretched body the brim of the pelvis was vertical; in the other drawing it was 52° removed from being in a straight line with the lumbar vertebræ immediately above it.

Some Observations on the Eggs of Birds. By John Davy, *M.D., F.R.S., &c.*

The author, after pointing out certain qualities of resemblance common to the eggs of different kinds of birds, such as especially the alkaline nature of the albumen and the acid of the yelk, and that the two are in opposite electrical conditions, described the results of the experiments he had made to endeavour to ascertain in what respects the eggs of different species differ. Some of the conclusions which his results seem to warrant are the following:—

1. As to the colour and markings of eggs, these are so very various, that the colouring-matter is of an organic kind very similar to that of leaves and flowers, and in part depends on molecular arrangements.

2. That the albumen in quantity greatly exceeds the yelk, but in eggs of different species in no regular manner, whilst in all the quantity of solid matter in the yelk is proportionally much larger than in the white.

3. That the temperature at which the coagulation of the albumen takes place varies in almost every instance, and that the firmness of the coagulum does not appear to be regulated by the proportion of solid matter which the albumen yields on evaporation.

4. That the coagulum of each has an aspect of its own, varying in different instances as to tint and degree of translucency, and in some varying in colour.

The author, taking into consideration the many sources of error to which experiments on eggs are exposed, offers his results, and the conclusions from them, merely as approximations.

Some Observations on the Blood, chiefly in relation to the question, Is Ammonia one of its Normal Constituents? By John Davy, *M.D., F.R.S., &c.*

Of the many questions relating to the blood, there are two, the author observed,

which have lately had much consideration:—one, as to the coagulation of that fluid, whether owing to the escape of ammonia? the other, whether the blood in a healthy state contains the volatile alkali? Referring to the first question, he stated his reasons for answering in the negative. The second question is, he thinks, more difficult to answer. The conclusions which he thinks are warranted by the results of varied experiments which he has made, are the following:—

1. That they are confirmatory of the inference that the coagulation of the blood is not owing to the escape of ammonia.

2. That they are favourable to the conclusion that the blood generally contains a minute portion of ammonia.

3. That the ammonia which is found in the air expired in respiration, and in the insensible cutaneous perspiration, is derived from the blood, and is yielded in union with carbonic acid.

4. That the proportion of the volatile alkali is greater in venous than in arterial blood, and in the blood of the Batrachians and of other animals in which the aëration of this fluid is less perfect than in birds and Mammalia of higher temperature.

Notes on certain Parts of the Anatomy of a Young Chimpanzee. *By* Dr. Embleton.

In these notes, a general description of the young male, with dimensions of the trunk and extremities, and of the alimentary canal, is given. The dentition, vertebræ, and ribs are noticed. The muscles of the leg below the knee, and of the foot, are described.

The different parts of the encephalon, and the relation of the posterior lobes of the cerebrum to the cerebellum, are reviewed.

The conclusions drawn are in conformity with the deductions of Prof. Huxley, namely:—1. That the posterior extremity of the Chimpanzee is a foot, and not a hand. 2. That the posterior lobes of the cerebrum in the Chimpanzee are developed so as fully to overlap the cerebellum, both laterally and posteriorly; and that all the parts of the human encephalon are represented in that of the Chimpanzee.

On the Reciprocal Action between Plants and Gases. *By* R. Garner, *F.L.S.*

In this paper the author brought forward the subject of the natural inhalations and exhalations of plants, and of the effects on vegetation of certain contaminations of the atmosphere, such as occur in coal and mining districts, consisting for the most part of sulphurous and hydrochloric acids and of ammonia. As regards the first question, he denied any power in ordinary plants to absorb watery vapour or water through the leaves, as exemplified by immersing the tops or leaves of drooping shoots in water, or by exposing them to a moist atmosphere. He noticed, too, that the avidity which water has for carbonic acid explains the facility with which it is taken in by the roots, or withdrawn by the juices of the leaves from the air. He guarded against this avidity in his experiments by covering the surface of the water in the bell-glasses containing his plants with a stratum of oil; and thus it may be clearly proved that growing plants or plucked leaves rapidly absorb in the sun a large amount of carbonic acid, though an atmosphere containing one quarter or one half of the same has in a short time an unhealthy influence on them. With respect to their exhalation of oxygen in the sun, he found that about 160 square inches of the upper and lower surface of young holly-leaves gave off in a long summer day $1\frac{1}{4}$ in. of oxygen, or a holly-bush about breast high 40 in. in the same time. Plants, even if healthy and growing, give off carbonic acid in the dark, so did the petals of plants even in sunshine, though in some cases no gas at all. Autumnal leaves appeared to absorb oxygen. With respect to the second point—the injurious effects of certain vapours upon plants—he observed that those mentioned above appear to act as corrosives. That they all are given off in the districts in question is shown from the deposit of sulphur and muriate of ammonia to be seen upon the scoriæ of the mine-heaps. Phosphorus and coal-gas are less prejudicial than those above-mentioned; pure hydrogen, nitrogen, and the vapour of chloroform still more innocuous. In fact, plants having no nervous centre are not

easily poisoned, except by corrosives, or by excess of stimulus to the roots—too much guano for instance; delicate plants may be watered with a solution of morphia or of hydrocyanic acid with impunity. With respect to chemical impurities of the air, different plants have different susceptibilities for such influence, and the greater or less impurity of the atmosphere may, indeed, be shown from the effects on plants. Thus the rhododendron will flourish in an air fatal to the common laurel; wheat will luxuriate when a holly or oak will die. Some plants which appear naturally to luxuriate in the coal strata—as the oak, holly, or some ferns—die when the mines begin to be worked. Fortunately, annuals suffer least; for instance, corn and wheat do well where nothing else can, and perhaps the exhalations in question may even tend to ripen them. An increasing deterioration of the atmosphere in towns and mining districts may be estimated by means of plants as follows:—1. In the smallest degree of impurity trees are destitute of the leafy lichens; and Ericæ, the Scotch fir, and the larch die. 2. Next, the common laurel, the Deodara cedar, the Irish arbutus, the laurestinus, and the yew die. 3. The araucaria, the thuja, the common cedar, the mezereon, and the Portugal laurel die. 4. The common holly, the rhododendron, the oak, and the elm die. 5. Annuals still live, and the almond, poplar, and many roses thrive, fruit-trees are barren, peas unproductive. 6. Hieracia, *Reseda lutea*, the elder, some saxifrages and sedums, with many syngenesious and cruciferous weeds still luxuriate.

On a Parasitical Acarus of the Anodon. By R. Garner, *F.L.S.*

The little Arachnoid in question inhabits the gills of the Anodon, and was fully described as the *Atax ypsilophora* by Van Beneden. The author also worked out its history: the ova, deposited in the mantle of the mollusk; the larvæ, with rostrum; the eyes, at first four and then two in number; moulting, and till the last moult *minus* one pair of legs. The author attributes the formation of pearls *par excellence* to the presence of a distoma. Around these parasites, as nuclei, shelly matter is deposited, sometimes at first dark in colour, sometimes clear nacre from the commencement. Hence pearls may have a dark centre or not, or, if the dark deposit goes on, a black or purple pearl may be formed. It is sometimes impossible to distinguish a distoma from an incipient pearl, except by pressure, when the pearl will burst; or polarized light will show the layer of shelly matter, or frequently the organization of the distoma may be seen through the nacreous covering. But other irritants may, *exceptionally*, the author admits, give rise to the formation of pearls or pearly prominences, as for instance the ova of parasites. Those of the *Atax*, when they are deposited in the *external* layer of the mantle of the mollusk, produce numerous pearly prominences to be seen upon the interior surface of the shell towards the retral extremity.

Further Observations on the Normal Position of the Epiglottis. *By* George D. Gibb, *M.D., M.A., F.G.S.*

When this subject was brought before the Association last year, it was the generally received opinion that the epiglottis in the healthy state was always erect and perpendicular. Its peculiar structure favoured this view. The examination of 300 healthy persons, up to the month of October 1862, has shown the author that, in a certain percentage, the cartilage was in a semipendent, transverse, oblique, or nearly quite horizontal position. This was during passive examination, independently of the act of swallowing, of phonation, or of any motion in the structures of the throat, and carefully observed when the tongue was protruded forward and held outside the mouth. Up to the present time, he had examined as many as 680 persons, of various ages and sex, all more or less in perfect health, or nearly approaching to it, and the percentage, curiously enough, remained the same—namely, eleven; that is, eleven persons out of every 100 individuals possess an epiglottis whose position is not erect. This striking difference between an erect and a pendent epiglottis is a question of the highest importance in everything appertaining to voice and throat, whether in health or disease. The pendent condition of the epiglottis is sometimes congenital, and, when it occurs in the young, there is great danger to life during their passage through the diseases of child-

hood, especially those likely to involve the throat. As vaccination in the young is a preventive or modifier of small-pox, so may the knowlege of the condition of the epiglottis act as a safeguard in the treatment of diseases of the throat, more particularly in such terrible affections as croup, diphtheria, and the different forms of œdema of the larynx from scarlet fever or other disease.

On Voluntary Closure of the Glottis, independently of the Act of Breathing. *By* George D. Gibb, *M.D., M.A., F.G.S.*

Voluntary control over the muscles of the larynx has been surmised, but never proved. In certain individuals, however, complete voluntary power is possessed over the laryngeal muscles; and this was discovered in the course of some experiments performed by the author upon his own larynx with the aid of the laryngoscope. They showed that the action of the posterior crico-arytenoid and the thyro-arytenoid muscles could be excited at pleasure by the will, without phonation and independently of the act of respiration; that is to say, breathing was interrupted for a few moments, and muscular action induced, the resulting appearances being seen in the laryngeal mirror.

It is considered to be more than probable, nay, almost certain, by some of our best physiologists, that all the muscles of the larynx are in a state of action during phonation; and through the general harmony and sympathy which exists everywhere amongst groups of muscles associated for one common purpose, it is assumed with perfect correctness that their states of action and relaxation are adjusted in such nicely balanced proportions as to produce the effect required by an education and practice of which the will is scarcely cognizant. *A priori*, therefore, if voluntary power is possessed over one set of muscles, it must be equally so in neighbouring groups, because of this harmony and sympathy existing among such muscles as those of the larynx in phonation.

Whilst one group is therefore *seen* to act through voluntary power, it is but reasonable to assume that other groups are simultaneously influenced by the same agency; and this can be proved to be correct.

In the author's larynx, if he deeply inspires and forcibly or strongly draws in the air, the glottis is seen widely open, the thyro-arytenoid muscles and vocal cords are drawn laterally outwards, and under favourable circumstances the trachea can be seen throughout its entire length, permitting of a view of its bifurcation and commencement of the bronchial tubes. This act is accomplished during breathing by the action of the posterior crico-arytenoid muscles.

If, on the other hand, the breathing is arrested for a few moments, and the action of the little muscles excited by the will, there is seen a remarkable phenomenon, which consists in the opening and shutting of the glottis with extreme rapidity, in the same manner as the blades of a pair of scissors.

The glottis may be retained of a triangular shape, perfectly motionless, or kept quite shut, the edges remaining in contact, at pleasure. So complete is the control over the laryngeal muscles in the author, that the balance of contraction and relaxation of the fibres may be so accurately regulated as to retain the glottis of any form, size, or width, at will, for some seconds, without an inspiration.

When the lips of the glottis are in contact, and so retained, the pressure is such, during the muscular contraction, that the fibres of the aryteno-epiglottic or Hilton's muscle are set in action, and the epiglottis is drawn downwards, and to some extent conceals the glottis. This last phenomenon further proves the voluntary power possessed over a set of fibres which were considered as the least likely to be under the control of the will, for their action was called spasmodic or convulsive, which permitted of the rapid passage of the food over the glottis and its precipitation into the œsophagus.

According to Bishop, the posterior crico-arytenoid muscles alone open the glottis, while all the rest close it. As the reflection of the voluntary action of the thyro-arytenoid muscles can be seen, of necessity the arytenoid and lateral crico-arytenoid act at the same moment, and as their fibres relax, those of the posterior crico-arytenoid contract, and thus the glottis is opened and shut by the will, during the alternate and simultaneous action of these muscles whilst respiration

is temporarily suspended. For the moment the author hazarded the opinion that the voluntary muscular power begins in the crico-thyroid muscles in approximating the two cartilages and rotating the cricoid on the thyroid, thus forming a *point d'appui* for the continuance of muscular action in the other laryngeal muscles, although the crico-thyroid exert at the same time their own influence on the tension of the vocal cords when they depress and draw forward the thyroid and raise and tilt backwards the cricoid cartilage, at the same time rotating the one cartilage upon the other.

The author's experiments he considered conclusively settled the question that in some persons, and probably in all if attempts were made, true voluntary power is possessed over the muscles of the larynx, and to such an extent that the glottis may be closed with a distinctly audible flapping noise, chiefly by the powerful and rapid contraction of the thyro-arytenoid muscles and their coordinate assistants, but especially the crico-thyroid, which, equally with the thyro-arytenoid, regulate the tension, position, and vibrating length of the vocal cords.

On the Renal Organ (the so-called Water System) in the Nudibranchiate Mollusks. By A. HANCOCK.

On the Physiological Effect produced by Apparatus contrived for the purpose of causing a Vacuum upon the entire Body, or a part thereof. By DR. JUNOD.

How to Restore Drowned Persons, Patients in Chloroform Accidents, &c. By CHARLES KIDD, *M.D., Member of the Royal College of Surgeons, England, Associate of the Surgical Society, Ireland.*

Since the previous Meeting of the Association, one very remarkable instance of accident from inhalation of chloroform vapour had come under the personal notice of the author, which he was desirous to bring before the Section. It has been a sort of *experimentum crucis* to prove the truth of certain views recently promulgated by him (as our volumes of 'Transactions' will testify), which it is not necessary here again to state in detail. It has been a sort of *experimentum crucis* performed in a case of suspended animation in an hospital patient from chloroform, where certain manipulations, which have proved effectual in hundreds of experiments on the lower animals, poisoned on purpose by chloroform, have also proved unexpectedly valuable in saving human life in this instance.

In these previous papers (it may be shortly stated) the author showed that from a large number of experiments on animals with anæsthetic vapours, especially by contrasting the effects of ether, chloroform, carbonic acid, carbonic oxide, &c., while the two latter disorganized the blood, and ether produced a kind of deep intoxication like alcohol, the effect of chloroform (while less persistent) was that of a more useful anæsthetic for general purposes. It was shown that chloroform did not act very materially on the blood, or cause intoxication; and, moreover, that where deaths unhappily occurred from chloroform, the accident was not necessarily due, as previously taught in the schools, to deep narcotism or paralysis of the heart's action ("cardiac syncope"), but rather to narcotism or paralysis of the voluntary respiratory nerves and muscles, which, in a secondary manner (but only in an incidental and not important manner), induced, as a post-mortem result, this so-called state of cardiac syncope.

The author also explained, at considerable detail, the nature and probable proportion of accidents from this cardiac syncope, or, as he now prefers calling it, APNŒA or muscular apnœa, as also the probable proportion or percentage of accidents that happened (perhaps as coincidences) during a state of simple SYNCOPE; the *modus operandi* of these proximate or immediate causes being different, as also the plan of resuscitation adapted to apnœa or to syncope being different, founded on this mode of operation of these causes.

It was explained at some length, that the present discovery of the true nature

of chloroform accidents is of singular importance, as it bears in a marked manner on the entire physiology of apnœa, viz. the apnœa and treatment of persons drowned, the resuscitation of still-born children, the recovery to life of patients suffocated in coal-mines, or individuals dug in a state of apnœa out of the ruins of tumbled-down houses, or even the restoration to life of persons "found dead" in bed at night from the effects of an overloaded stomach (from indigestion) pressing on the diaphragm, but oftener ascribed to a mythical disease, "fatty heart."

Reasoning deeply on various groups of facts, partly practical in hospitals, partly pathological, partly experimental on animals, as seen in the dead-house, partly empirical from observations now of some ten thousand administrations of these agents, the author leans to the belief that, under chloroform or ether, the heart is never attacked by the sudden paralysis which popular fancy as also some writers have sought to convey by the words cardiac syncope: we have had an erroneous or wrong interpretation of the facts.

He contends, as a matter of reasoning, that if in one hundred experiments on dogs, rabbits, &c., poisoned by chloroform, the most marked or only marked post-mortem appearances be gorging of the right cavities of the heart, if in the human subject the same condition of the pulmonic or right heart be found, as it is, the previous statistical or bare induction from the facts that this gorging of the heart is the result of paralysis from chloroform (cardiac syncope), and the immediate cause of death, is not true, as there has been an anterior condition more important overlooked, viz. that this gorging of the right heart is merely the result of (apnœa or) the lungs not receiving the blood from the heart thus vainly striving to push it forward; it is the function of the lungs and diaphragm, in a word, that is at fault, and what has been overlooked by mere experimenters of a vivisectional kind on animals; that, in hospital, the patients under chloroform usually struggle very violently, as if suffocating; and also when alarm of accidents arises, the patient's limbs are actively rubbed in the course of the veins, all which tends powerfully to engorge or fill the right side of the heart: the heart, in fine, strives actively to push forward this blood; but the lungs are in a state of paralysis, and do not receive it.

Electricity to the *heart* is useless in all these cases; but electricity to the diaphragm and respiratory muscles, as causing full artificial respiration, unloading the lungs and heart-cavities, &c., acts like magic. To support his view, other logical deductions were quoted by the author. It is against the analogy of the action of chloroform, so peculiarly confined to muscles of the voluntary kind, that it should act on the heart. It is contrary to all clinical observation of the pulse and action of the heart in thousands of hospital cases deeply narcotized, the pulse being almost always increased in volume and strength, even so much so that some good observers can see no explanation of the deaths but by over-stimulation and over-action which induce this gorging of its cavities: the heart, in experiments under chloroform, is, in fact, *ultimum moriens*. Again, it often occurs that the pulse, before taking chloroform, may, in patients, be almost imperceptible and very slow, with a heart equally feeble, but both improve in force and number of beats as the narcotism of the chloroform becomes more and more advanced: even Dr. Snow describes the pulse as thus usually increased in force by chloroform—a paradox he admits he cannot explain. Again, the deaths from chloroform do not usually occur from or in deep narcotism or coma, but generally in the stage of excitement or half-narcotism, and want of proper relation of the capacity of the lung (diminished perhaps) to the supply of blood in excess crowded into or engorging the large veins and right auricle and ventricle: a form of tetanic rigidity, with spasm of the glottis, explains the condition.

Comparing thus one group of facts with another group, the best form of deductive reasoning, the error in the earlier hasty generalization is corrected; and when we remember that there have been now nearly 200 deaths in surgical operations from this mistake or generalization, its correction becomes a matter of grave importance. The remedy which promises such good effects, which was used in the case of the poor lady dead from chloroform, the subject of the present communication (and has since been referred to in the leading medical journals in three other instances of apnœa from chloroform accident or drowning, with the same admirable good re-

sults), is the "Faradization" form of electricity, (not applied to the heart, but) solely to or through the respiratory muscles, diaphragm, phrenic nerve, &c., so as to assist or originate, apparently, the only true form of artificial respiration so desirable. This form of electricity cures hemiplegia, by renewing the vital activity of muscles paralyzed for a time by a clot in the brain; but the ordinary electricity is directed back along the nerve to the brain, already disordered, and does mischief, and near the eye, for instance, may cause total blindness. So that, where we have already the brain under chloroform, the "Faradization" plan acts better by stimulating merely the diaphragm and other respiratory muscles; the mode of application found best in animals being an intermittent but gentle current passed through the phrenic nerve (where the omohyoid muscle *in the neck* lies at the outer edge of the sterno-mastoid) by means of the wetted sponge (not the dry sponge),—the other pole or sponge also, as in this lady's case, wetted, applied somewhere about the floating ribs nearest to the diaphragm, or, still better, one or two acupuncture needles stuck at once into the latter muscle, so as to excite alternate action of the current from the neck to the respiratory muscles, and imitate normal respiration. In animals, this plan succeeds in a manner almost marvellous in restoring life where suspended animation exists.

The patient, in the present case, was a poor married lady, otherwise in fair health, admitted to one of our private hospitals or "homes," who was operated on by one of the plastic operations on the female organs, so successful of late, thanks, too, in a great measure, to the calming influence of chloroform. Near the end of the operation, the author (Dr. Kidd), who watched the respiration and pulse all through its performance, was alarmed by both stopping, then going on again, but finally stopping, with all the usual signs of death by chloroform; the woman, in fact, lay in a state that it might be said death had obviously set in: she was cold, pulseless, without motion or breathing, her face like stone. The utmost alarm was instantly felt. The so-called "ready method" of Marshall Hall, as also the Silvester method of artificial respiration, were persistently had recourse to; still there was no pulse, no breathing, no animation. The lifeless or all but lifeless body, in a word, lay, as many of the animals poisoned by chloroform are seen to lie, till roused up by electricity. The author of the paper sent at once for the magneto-electric battery. Some confusion arose at first in its application, as the handles or poles were not insulated, and the author himself was receiving the shocks, till a German physician, standing by, happily caught the metallic handles with his coat-tails (non-conductors). This little incident is mentioned to show how totally unprepared for such accidents our London hospitals are. All the persons standing by, too, were erroneously solicitous that the electricity should be applied at once to the *heart*; but the directions of the author were not to the heart at all, but to the phrenic nerve and diaphragm, as already described. The poor patient had now been lying some quarter of an hour pulseless, cold, and without breath, indeed pronounced "dead." Off and on, alternately, the moist poles were now applied about twelve times each minute, so as to imitate in somewise the stimulus of ordinary contractions of the diaphragm; and soon, to the delight of the operator and all around, a deep sighing inspiration was noticed at each break of the circle (this was a great relief), increasing in fullness till it was evident good respiration was established. No pulse, however, was yet perceptible, and cardiac action was still watched for with much eagerness. Minutes on minutes passed away as hours: the patient moaned at the excitement of the phrenic and a pin stuck into the diaphragm (the author's scarf-pin, as no other was to be had); but still it was thought desirable to continue the application of the electricity: there was soon a flicker of the pulse, but not till the expiration of two hours was the pulse quite reestablished. It is worth being added, that the woman quite recovered, and had no recollection whatever of the four hours her life was in the balance and under the surgical operation. The case, as already stated, is chiefly remarkable as fully bearing out the efficacy of this form of electricity, and applied only in this manner, as previously tried in hundreds of experiments on the lower animals. It has now been tried in four cases on the human subject. It places a serious responsibility on our London and other hospitals where the author's views have not yet been examined, and where deaths are occurring

very often; nor is it the least valuable portion of the present researches that they seem applicable to all forms of apnœa, whether from drowning, or chloroform, or suffocation in coal-mines, or resuscitation of still-born children, &c.—all forms of stoppage of heart, indirectly arising from want of artificial or natural respiration. The discovery may not appear so valuable or new to some who have not studied the subject, but it is eminently both one and the other, when taken in conjunction with the fact, only half known in the schools, that the "cardiac syncope" of the standard books does not begin at all in the heart, but (as the author's researches in previous volumes of 'Transactions' testify) in the lungs, and probably by a form of tetanic rigidity of the respiratory muscles.

On the Investigation of Instinctive Actions. *By* Dr. W. Murray.

The conclusion arrived at by the author was, that the instinctive movements of animals, and their nervous or psychical constitution, did not differ from those of man in kind, but in degree. Movements are classed by him under two heads:—1st. The simple, of which the volitional, emotional, and the reflex are varieties. 2nd. The compound, made up of two or more of the former. In man the volitional movements, as representing reason and experience, are immensely superior to the others. As we descend in the scale, we find emotion as the originator of the purely instinctive movements become more prominent. Lower still in the scale, we find all the movements necessary to the life of the animal left to the care and control of reflex action. The author concluded that the amount of intelligence possessed by animals may be estimated by the extent to which the volitional controls the emotional and reflex movements, inasmuch as volition is the representative of reason.

On the Practicability of Arresting the Development of Epidemic Diseases by the Internal Use of Anti-Zymotic Agents. *By* Dr. G. Robinson.

The author commenced by referring to the circumstance of the analogy between many of the phenomena of zymotic diseases and the ordinary process of fermentation having been perceived and recognized by Hippocrates and the oldest writers on medicine. Their idea was, that a poisonous ferment, existing in the atmosphere, entered the mass of blood, and induced in it a series of changes, which gave rise to the excessive heat and other peculiarities of that class of diseases. At the present time, this doctrine, modified by the discoveries of Liebig and other chemists, has been adopted by most physicians, and forms the basis of the classification of diseases framed by Dr. Farr, and used by the Registrar-General. It thus supposes living germs to exist in the atmosphere, which, when introduced into the body, give rise to a specific and regular series of morbid actions, pursuing a definite course in a definite time, as in small-pox—those germs being developed and multiplied, and producing others capable of reproducing in other bodies the same succession of changes. Other pathologists have supposed that the atmospheric poison acts on the blood chemically, by giving rise to what may be termed catalytic actions; while the author is disposed to believe, from what he saw during the cholera epidemic in Newcastle, in 1853, that some of these volatile organic matters in the atmosphere are capable of acting on the animal body as direct poisons, and that this inanimate volatile matter also furnishes nutrition to the organic germs suspended in the air. After these preliminary remarks, he proceeded to refer briefly to a number of scattered facts, which seemed to him to indicate the existence of a great principle, which might hereafter be found applicable to the prevention or mitigation of epidemic diseases, by the direct use of substances capable of arresting the process of morbific fermentation. He mentioned the following facts as converging to this conclusion:—1. Antiseptic substances, ranging from simple innocuous matters, such as sugar, up to the powerful metallic poisons, such as corrosive sublimate, and forming a very numerous and diversified group, have been long known to be capable of arresting the putrefaction of animal and vegetable structures. 2. The same substances prevent the formation of fungi, as is seen in the use of solutions of metallic salts in taxidermy, in the prevention of dry-rot, &c. 3. Many of those agents are

also known to arrest at once the process of fermentation—as, for instance, sulphurous acid; and Erni and other chemists have observed under the microscope the rapid stoppage of the vitality of the yeast-plant when a solution of arsenious acid was added to the fermenting liquor. 4. The formation of the fungus in and on the plant, which causes the vine disease, is prevented by applying sulphur to the affected vines. 5. In Cornwall, it is believed that the arsenical fumes from the tin-calcining furnaces exercised an influence over the potato plants in the neighbourhood, which preserved them from the disease then affecting other parts of the same county. [A statement to this effect, signed by Capt. Charles Thomas, sen., of Dolcoath, and sixteen cottagers, was here read.] 6. It has been found that when a species of fermentation has taken place in the human stomach, resulting in the development in large quantities of a minute organism (the *Sarcina ventriculi*), this morbid action can be controlled and stopped by the direct anti-zymotic influence of certain salts, such as sulphite of soda, in doses perfectly compatible with the patient's safety. 7. In different parts of the world, among different races, a belief has long existed that certain antiseptic substances, of which arsenic may be taken as the type, are capable of acting as antidotes or preservative and curative agencies against atmospheric and other poisons; and in some cases that popular belief has proved to be well founded. The experience of the multitude discovered the value of arsenic as a cure for ague long before it was recognized as such by physicians. The arsenical fumes of certain works in Cornwall were stated by the late Dr. Paris to have stopped the ague, previously endemic there. More recently it has been stated, that the arsenic-eaters of Syria are peculiarly exempt from fevers and other epidemic diseases; and in India the natives have long used arsenic as an antidote to the poison of snakes. Dr. Robinson concluded by expressing a belief that these scattered observations were not only sufficient to justify and necessitate further inquiries in this direction, but seemed in themselves to shadow forth the outline of a great law, which might at some future time be productive of immense benefit to mankind.

On the Nature and Varieties of Organic Effluvia. By Dr. G. Robinson.

Were any proof wanting of the intimate and necessary connexion between natural philosophy, chemistry, and natural history, on the one hand, and physiology and pathology on the other, it would be supplied by the gradual progress of our knowledge of the abnormal constituents of the atmosphere. As the natural sciences have advanced, many of those noxious influences which were formerly ascribed to supernatural causes, or to the scarcely less mysterious agencies of stars, comets, and volcanos, have, even in the present imperfect state of medical science, been traced to the operation of the ordinary laws of nature; and there is strong reason to hope and believe that with the advance of science the composition and relations of many of those subtle aërial poisons which sometimes periodically, sometimes permanently, desolate various regions of the earth will be ascertained, and their injurious effects at least in some degree mitigated or prevented. But for this great object to be even partially attained, the cultivators of the natural sciences must be brought into closer relation with physiologists and pathologists; they must, even for the advancement of their own favourite departments of knowledge, be willing both to receive and impart instruction, and so cooperate in the work of elucidating the laws of life with those men whose special duties compel them to observe, as closely as human powers extend, the structure and functions of the highest of all animal organizations. Even now, the necessity for further advances in the application of natural philosophy and chemistry to the explanation of the phenomena of life is painfully felt by every student of the healthy and diseased actions of the human body; and there are hosts of questions, all bearing most powerfully and directly on the health and happiness of mankind, which can only be solved by continued progress in the direction indicated. I make these preliminary remarks in no depreciatory spirit, and with a full sense of the enormous advances recently made in the development of the physical sciences; but I do feel that the highest, and noblest, and most useful study that can engage the human intellect—the study of man himself—has not in this country received a proper share of attention, while I am at the

same time convinced that its cultivation would in turn accelerate the progress of general science. A very little reflection will suffice to demonstrate that, under the general term "organic effluvia," several entirely distinct substances have been confounded; and as it is impossible to entertain any clear ideas of their action as causes of disease, without greater precision in this respect, I am induced to direct attention to the subject. The importance of a clearer classification will be manifest when we consider that our arguments and inquiries respecting epidemic diseases must be materially influenced by the views prevalent as to the composition, properties, and affinities of those peculiar matters present in the atmosphere, which form the basis of such pathological and hygienic researches. In the present state of our knowledge, I am inclined to think that all those abnormal constituents of the atmosphere which are recognized under the general term "organic effluvia" may be resolved into four principal groups, viz.:—1. Gases and the vapours of volatile chemical compounds formed during the decomposition of organic matter. 2. Odoriferous particles *sui generis*. 3. Volatile organic matters not endowed with vitality. 4. Living germs. 1. In the first group I would place not only the binary gaseous compounds evolved, for instance, during putrefaction, such as the compounds of hydrogen with sulphur, phosphorus, carbon, &c., but also ammonia and its curious combinations with sulphur and phosphorus, described by Dr. Crace Calvert as formed during the decomposition of animal matter. 2. The natural philosophy of odours is so little known that no excuse need be offered for placing in a separate group the volatile particles capable of being detected by the sense of smell, but not demonstrably related to any known gases or vapours. 3. The third class of organic effluvia is one to which I attach great importance from the belief that not only are those volatile organic matters often, perhaps generally, poisonous in themselves, but that they are also injurious to an incalculable extent by sheltering, nourishing, and so propagating the noxious germs liable at all times to be suspended in the atmosphere. And if it can be demonstrated that volatile organic matter is present, under certain circumstances, in the air surrounding us, there is no more difficulty in believing it capable of nourishing and contributing to the growth and development of contiguous germs, than in supposing the animalcules present in water to derive their chief support from the animal and vegetable matters dissolved or suspended in it. That organic matter is present in the atmosphere might at once be inferred from the varied odours proceeding from plants and animals, and from the injurious effects exercised on living animals by exposure for a length of time to accumulations of such effluvia. But modern chemistry has converted this probability into a certainty. Vauquelin, on analyzing the liquid obtained by the decomposition of marsh *deios*, found in the residue an organic substance which blackened or charred on exposure to heat. Zimmerman has described, under the name of "pyrrhine," volatile organic matter universally present in rain and snow-water. And more recently Dr. Angus Smith has even determined the relative quantity of the organic constituents of the atmosphere present under different circumstances. This point may, therefore, be considered as definitely settled. 4. The existence of living germs in the atmosphere is proved by the phenomena of what has been erroneously called "Equivocal Generation," such as the appearance of fungi on animal and vegetable substances secluded from everything but the atmosphere, air, &c. The possible dependence of epidemic diseases on the entrance into the blood circulating within the human body of some varieties of these organic germs is favoured by many analogies and by some direct evidence. For instance, Dr. Robert Dundas Thompson, who examined the air contained in the cholera-wards of St. Thomas's Hospital during the epidemic of 1854, states "that in the atmosphere of a cholera-ward mechanical matters were diffused throughout the air, derived from the inmates; that sporules of fungi, and germs of vibriones, or vibriones themselves, were obtained by filtration from the atmosphere." In leaving this subject for the present, it may be well to observe, that whatever classification of these volatile invisible particles emanating from living or dead animal and vegetable matter may eventually be adopted, they are doubtless so mixed together as to render their separation in any definite quantity of air very difficult, if at all practicable. For instance, in the effluvia proceeding

from a case of small-pox it could be demonstrated that all the above-described varieties are present. And, in fact, there is every reason to believe that the atmosphere is even more compound than the ocean, containing innumerable substances dissolved or suspended in it, and being constantly affected by and reacting on the mass of living organisms with which it is brought in contact.

On the Condition of the Uterus after Delivery in certain of the Mammalia. *By* Professor ROLLESTON, *M.D., M.A., F.R.S.*

The author gave descriptions of the uteri of the common Rat (*Mus decumanus*), of the Tenrec (*Centites ecaudatus*), and of the human subject, in each case giving the appearances seen immediately after or at the period of parturition. He described, also, and figured the uterine walls and the fœtal membranes of a Pig-tailed Monkey (*Macacus nemestrinus*), which had died a short time after parturition. Special reference was made to Dr. Matthew Duncan's paper in the last volume of the 'Obstetrical Society's Transactions,' and to M. Robin's paper in the 'Mémoires de l'Académie Impériale de Médecine de Paris' (tome xxv. 1861). These authors had shown that, in the human subject, one part, and that much the larger part, of the so-called "decidua serotina" was really not deciduous at all; and M. Cazeau ('Traité des Accouchements,' p. 500) had stated it as his belief that the non-deciduous serotina was often mistaken in practice for a morbidly adherent placenta. In theory it had often been mistaken for a mass of denuded muscular coat, being, as it was, made up of smooth and glistening strata of membrane, which it was necessary to examine with the microscope to be assured that it was not the muscular but a modified mucous coat. The non-deciduous serotina in the Rat did not form, as in the human subject, an elevated area, but a hernial protrusion out of the uterine cavity into the mesometrium. This had been mistaken for a developing ovum. M. Robin's phrase, in describing the way in which the utero-placental area and the laminæ of non-deciduous serotina were restored to the condition of the rest of the uterine mucous surface ("le tissu de la muqueuse s'est régénéré *au-devant* d'eux"), was shown to apply to the process of restoration in the homologous area and tissues in several of the lower animals; and it was suggested that the process of reparation of extensive superficial wounds bore a considerable resemblance to the more purely physiological phenomenon under consideration. M. Coste's plate ('Histoire du Développement,' 1. a. fig. 3), however, showed for what a long period the utero-placental area might retain characters more or less different from those of the rest of the mucous membrane of the cavity. In this point, the Rodent and Insectivore contrasted forcibly with the human subject. The deciduous serotina it was not always easy to separate away from the after-birth, at least so as to preserve it in the form and dimensions it had normally in the human subject previously to parturition. In the Monkey it was more coherent and consistent, and was so figured by the author, as well as by Breschet in the 'Mémoires de l'Institut' (xix.), in a paper less known than it deserved to be. In the lower Mammalian orders, the Insectivora, Rodentia, and Carnivora, the deciduous serotina was thicker, more pulpy, and less condensed than the homologous structure in the Quadrumana and in the human subject. The Cetacea, the Pachydermata (resembling them in so many points), and the Ruminants had no deciduous serotina. This structure was saucer-shaped in the Rat, and might be found in the stomach of the mother rat after parturition, together with the after-birth, which these animals, as well as many others below the apes, devoured. It was bilobed, but the two lobes were continuous centrally, though constricted, in the Rabbit; the decidua serotina, in fact, clamped the bilobed after-birth together. The same was the case with the Hare; but the two lobes of the after-birth itself were here connected by an isthmus of their own proper tissue, as well as by the decidua serotina. The decidua was but a thin wafer in the Tenrec at full time: in a Hedgehog, at an early period, it was tumbler-shaped,—the bottom of the tumbler being supposed to be convex, and the rim to converge somewhat.

On Life in the Atmosphere. *By* J. Samuelson.

No subject in natural history, except the allied one, the origin of species, had of late excited greater interest in the scientific world than the origin of the lowest types of living beings on the globe; and although the problem was far from being solved, yet the investigations that had accompanied the discussion had already served the useful purpose of throwing new light on the anatomy and life-history of the mysterious little forms of which it treated. It was rather with the latter object, than in the expectation of being able to assist in the solution of the general question, that the author ventured to lay before the Association the results of investigations recently made. He had, for example, taken rags imported from various countries, and shaken the dust from them into distilled water, which he then exposed to the atmosphere; and after describing generally the character of the living forms he had discovered in this pure water, he stated in detail the forms of life found in each kind of dust, and among these were some new species of Rhizopoda and Infusoria, and an interesting ciliated worm-shaped form, originally a Vibrio, but which grew in dimensions until it assumed the appearance of a collection of the larvæ of some other Infusoria. The general result of the microscopical examination of these fluids between the 27th of July and 15th of August was as follows:—In the dust of Egypt, Japan, Melbourne, and Trieste, life was the most abundant, and the development of the different forms was rapid. He also described the infusorial forms found in pure distilled water after a few days' exposure to the atmosphere. In conclusion, he observed that if he was correct in supposing the germs of the living forms that he had described to be present in the dust conveyed by the atmosphere, and in distilled water, it was worthy of notice that these germs retain vitality for a long period, of which he could not pretend to define the limit. In his experiments they outlived the heat of a tropical sun, and the dryness of a warm room during the whole of the winter; but in Dr. Pouchet's case they retained their life 2000 years, for he obtained his from the interior of the pyramids of Egypt, and they survived an ordeal of 400° of heat. A main purpose which the author had in view was to disprove the theory of spontaneous generation; and he suggested whether the great rapidity with which these germs are multiplied might not account for the spread of epidemic diseases. He did not profess to have any acquaintance with such diseases; but might it not be desirable to subject the atmosphere of hospitals to the microscopic test?

On the Dietary of the Lancashire Operatives. *By* Dr. E. Smith, *F.R.S.*

Dr. Smith explained at some length an inquiry into the dietary of the Lancashire operatives made by him for the Government, with a view to show the minimum allowance of food to maintain health, and the most economical mode of expending the amount. The Report had just been published in the Fifth Report of the Medical Officer of the Privy Council, and in the paper he showed—1st, the amount and cost of nutriment which those populations obtained in times of plenty and scarcity, contrasting the amount in the same person under the two conditions; 2nd, the amount which should be allowed for food is 2*s.* 3*d.* to women, and 2*s.* 6*d.* to men, weekly; 3rd, the formulæ for soups and other foods distributed to these classes; and 4th, numerous formulæ arranged by Dr. Smith to show how much nutriment could be obtained from ordinary foods for the sum allowed.

On the Dietaries of the Labouring Classes. *By* Dr. E. Smith, *F.R.S.*

In this paper Dr. Smith pointed out the value of various foods in relation to their cost and nutritive elements, and particularly the extreme value of bread, skimmed milk, and butter-milk in the dietary of the poorer classes. The carbon and nitrogen in the nutritive elements were alone selected, and the price of the foods was such as applied to the greater part of the country. The following table contains some of the results at which he arrived:—

TABLE showing the quantity of Carbon and Nitrogen contained in 1*d.* worth of various foods at the prices annexed, and also the variation from the pennyworth of various foods to supply as much Carbon and Nitrogen as are contained in one pennyworth of bread (the standard quantity).

Food.	Costing		Carbon for 1*d.*	Nitrogen for 1*d.*	Variation from cost of 1*d.* to supply the standard quantity of 1450 grains of carbon and 66 grains of nitrogen.	
					Carbon.	Nitrogen.
	s.	*d.*	grains.	grains.	*d.*	*d.*
Bread		$1\frac{3}{8}$ per lb.	1450	66	..	..
Fine flour		2 "	1330	60	1·09	1·1
Barley		1 "	2500	93	·58	·7
Rice		2 "	1380	35	1·05	1·88
Oatmeal		$1\frac{4}{5}$ "	1513	75	·957	·88
Maize		1 "	2800	121	·51	·545
Peas		$1\frac{1}{2}$ "	1820	170	·796	·388
Potatoes		$\frac{1}{2}$ "	1540	49	·94	1·34
Potatoes		1 "	770	$24\frac{1}{2}$	1·88	2·69
Green vegetables		$\frac{1}{4}$ "	1640	56	·88	1·18
Green vegetables		$\frac{1}{2}$ "	820	28	1·76	2·36
Butter	1	2 "	327	..	4·43	..
Lard		9 "	591	..	2·45	..
Dripping		6 "	886	..	1·63	..
Suet		7 "	651	..	2·22	..
Sugar		$4\frac{1}{2}$ "	622	..	2·34	..
Treacle		3 "	746	..	1·94	..
Beef		$7\frac{1}{2}$ "	320	23	4·53	2·87
Mutton		7 "	415	20	3·49	3·3
Pork		7 "	483	18	3·0	3·66
Liver		3 "	410	70	3·53	·94
Bones		$\frac{1}{2}$ "	1566	48	·92	1·46
Dried English bacon		$8\frac{1}{2}$ "	510	12	2·84	5·5
Green American bacon		$4\frac{1}{2}$ "	918	17	1·58	3·88
Dried herrings		$\frac{3}{4}$ each.	352	54	4·1	1·22
Fresh herrings		$\frac{1}{2}$ "	480	72	3·0	·91
New milk		1 per pint.	546	44	2·66	1·5
New milk		2 "	273	22	5·32	3·0
Skimmed milk		$\frac{1}{4}$ "	1748	147	·82	·38
Skimmed milk		$\frac{1}{2}$ "	873	87	1·64	·76
Skimmed milk		1 "	437	44	3·28	1·52
Butter-milk		$\frac{1}{6}$ "	2514	262	·576	·25
Butter-milk		$\frac{1}{2}$ "	838	88	1·15	·75
Whey		..	..	..	..	..
Skimmed-milk cheese		3 "	782	122	1·98	·54
New-milk cheese		8 "	332	40	4·33	1·65
Tea		3 per oz.	..	3·3	..	20·0

On Cranial Deformities, more especially on the Scaphocephalic Skull. By WILLIAM TURNER, *M.B., F.R.S.E.*

The author commenced by stating that deformities of the skull might be occasioned by artificial means, by pathological changes, by posthumous changes, and by developmental irregularities and deficiencies. He in a great measure restricted himself in his paper to a consideration of the effects produced on cranial form by developmental irregularities and variations in the mode of ossific formation, more

especially by premature or retarded union of the cranial bones along their sutural lines and at their synchondroses. He arranged the sutures connecting the bones of the skull-cap into a vertical transverse group, a median longitudinal, and two lateral longitudinal groups; and agreeing with Professor Virchow, of Berlin, he stated that should a premature ossification take place in one, or more than one, of the whole, or a part, of a line of sutures, then the growth of the skull corresponding to, and in a direction perpendicular to, the line of synostosis will occur, and diminished length, or breadth, or height, as the case may be, will be occasioned. He illustrated this proposition by describing a peculiarly elongated and laterally compressed form of skull, to which, along with Professor Von Baer, of St. Petersburg, he applied the name scaphocephalus. Four as yet undescribed examples of this peculiar boat-shaped skull had come under his notice. The whole of these crania were characterized by possessing the following characters:—absence of a sagittal suture, and consequent blending of the two parietal bones; absence of parietal eminences; lateral compression; great elongation. He then discussed at length the two theories which had been advanced to account for the production of such a form of skull; and concluded that the balance of evidence was in favour of the theory that it originated from a premature union of the sagittal margins of the two parietal bones, and consequent compensatory growth of the skull in the antero-posterior direction, rather than from the development of the bi-parietal bone from a single median vertical centre. The author then directed attention to the importance of attending to the above proposition in ethnological inquiry, more especially with reference to the production, through its action, of various aberrant forms of skull in individuals of any given nationality, which may cause them to possess a shape of head quite different from that of the race to which they belong. He pointed out, moreover, that obliteration of the sutures to a greater or less extent exists in the crania of the Flathead Indians, which have been distorted by artificial means; his observations agreeing with those of Professor Daniel Wilson in this particular. He was of opinion that the pressure occasioned the tendency to premature union of the bones in these cases. The author did not think that persons possessing crania the form of which had been modified by premature synostosis necessarily exhibited any special tendencies to cerebral disease or deficiencies in their mental capacities. The paper is printed at length in the 'Natural History Review,' January 1864.

On the Means of passing unharmed through Noxious Gases or Vapours. *By* John White, *Surgeon, Finchley.*

It consists of two flexible pipes fixed in a metal covering, which is fixed over the nose and mouth. Each of these pipes is furnished with a valve of vulcanized india-rubber, one of which is fixed so that it can be moved only inwards, and the other only outwards. These valves are elastic, and of so light a material that they are opened and shut by the force of the air, moved to and fro in the act of breathing; and, therefore, when the air passes through these pipes, the person inhales only through one pipe, and exhales through the other. Having the end, which is farthest from the body, of that pipe by which he inhales in a pure atmosphere, the air which enters the lungs is pure, though the person is surrounded by noxious vapour. This inhaling-pipe may draw its supply from the open air at any distance from the body, or it may be supplied from a bag carried on the body. By *this* plan, the supply is limited to the size of the bag; by *that*, the supply is limited by the length of his inhaling-pipe. The flexible valve of the exhaling-pipe completely prevents ingress of the surrounding gas, and therefore the pipe is short; it need not be more than half an inch in length. The part of the apparatus which I have described, and which I call the "ori-nasal cover" and air-pipes, is fixed in that part of an air-tight hood which covers the face. A tippet, made of waterproof cloth, is joined to the hood. Two circular pieces of glass are fixed in the hood for enabling the man to see. Every part of this air-proof hood where the metal is fixed is water-tight. When this apparatus is about to be used, a soft, thick kerchief is to be wrapped smoothly round the neck. The hood and tippet is then put on. A band is bound round the head and face, over the hood, to keep

the ori-nasal cover in its place. A kerchief is bound round the neck over the tippet, to prevent any foul air passing under it; and the waistcoat and coat should then be buttoned and secured over the tippet for the same purpose.

On the Coal-Miners of Durham and Northumberland, their Habits and Diseases. By Dr. Wilson.

Premising that disease, like life, was not an entity *per se*, but a modified vitality, the object of this paper was to show what effect the exclusive habits and occupation of the coal-miners of the North of England had on their health and length of life. The author described at length the construction of the cottages, the dress, the food, the nature of the work, and the pastimes of the pitmen.

Their houses are well adapted for good ventilation. Their dress is the best for resisting the effect of the change of temperature in going to and returning from work. Their food is wholesome, and, although eaten somewhat irregularly, the customs they adopt are well suited to their peculiar circumstances. The division of labour is fully carried out. They work in a constrained position—each hewer working alternately one week from 1 a.m. till 9 a.m., and in the next from 9 a.m. till 5 p.m. They eat a moderate quantity of animal food once a day, generally on returning from work: after this meal they give themselves a thorough cleansing with soap and hot water, and then they retire to rest. They have favourite amusements, and many of them indulge periodically in great excesses. Ale is the liquor chiefly drank, and that by some in large quantities; but the *régime* of a colliery is so strict that, however much they may exceed on receipt of their wages, they must resume work at the proper time; and thus habitual drunkenness is prevented, and consequently the specific diseases induced by alcohol are extremely rare.

The most frequent cause of death amongst them is accidental violence. The miners of Durham and Northumberland are not prone to phthisis, and there is almost a total absence of the black phthisis which is so common in some mining districts.

The impure air they often unavoidably breathe brings on structural changes in the mucous membrane of the lungs, and the consequent oppressed breathing is a very common ailment. According to the author's experience, they are almost exempt from Bright's disease; and he attributes this to their profuse perspiration while at work, and the daily ablution with soap and hot water on their return home.

Having gone with some minuteness into the statistics taken by Dr. Farr from the census of England, the author drew the conclusion that the miner of the north of England has an average of three years' longer life than the aggregate of Englishmen, eight years' longer life than the Cornish miner, nine longer than the Staffordshire and twelve longer than the South Wales miner, and only one year less than that of the men of the healthiest districts of the kingdom.

These results were in accordance with the author's personal observations, and were also borne out by statistics taken by him from the local registers of his neighbourhood. Pitmen marry young, and are thus freed from a large class of imaginary and real disorders; and the author concludes, that whilst there is much need for amendment in their morals, their physical condition should not be interfered with.

GEOGRAPHY AND ETHNOLOGY.

Address of the President, Sir Roderick I. Murchison, *K.C.B., D.C.L., LL.D., F.R.S., Director-General of the Geological Survey, and President of the Royal Geographical Society.*

A quarter of the present century has elapsed since it fell to my lot, as Joint General Secretary of the British Association for the Advancement of Science, to address the numerous and influential body which in 1838 was assembled at New-

castle-on-Tyne, and presided over by the late Duke of Northumberland. Under the auspices of that good and enlightened nobleman, we then gathered together much pecuniary aid for the advancement of Science; and, including Ladies (who, however, were not then members, but visitors), our numbers were greater than on any occasion before or since at any place in the British Isles. I was then associated in duty with that eminent mathematician the late Dr. Peacock, afterwards Dean of Ely, who, with many of our leading members, has, alas! passed away. Those of us, however, who are left come again hither with a lively recollection of the kind reception we then met with, and therefore sanguinely anticipate that Newcastle and the Counties of the North of England will well sustain their former good name and high reputation.

In 1838 this town had been so recently embellished by such new and beautiful architecture that, in our opening General Assembly, I spoke of the noble results of individual enterprise, genius, and taste which had associated the triumphs of art with those of manufacture and commerce, and combined the refinements of wealth with the most varied productions of industry.

The words of the Latin poet, which I then quoted, have, indeed, in later years been rendered still more applicable:—

> "Hic portus alii effodiunt; hic alta theatris
> Fundamenta locant alii, immanesque columnas
> Rupibus excidunt; scenis decora alta futuris."

For, if I was then struck with the great works which this capital of the northernmost English counties had achieved since the early recollections of a boy at Durham School in the first years of this century, what is now my gratification and surprise when I look at the onward progress made between 1838 and 1863 in this centre of industry! In 1838 we were not enabled to reach our place of meeting by railroad from the south or from the north; but now the passenger flies across the Tyne by one of the noblest and most skilfully engineered of river-viaducts. Then, it is true, great and flourishing manufactories existed, and evidences of energy and high intellect abounded; but now among your townsmen there has arisen a man whose genius has thrown new light on the defence of nations, and whose talents and ingenuity have been so appreciated by the public, that the British Association could not have selected a more fitting President of their body.

Twenty-five years ago your trade and commerce were, it is true, important; but your imports and exports, including those of North and South Shields and Sunderland, have since then, as nearly as may be, trebled, and ships from the Tyne, the Wear, and the Tees now frequent the most distant regions of the globe.

It is especially by this great extension of its influence and relations that Newcastle-on Tyne has become an eminently suitable meeting-place for geographers and ethnologists; and to this fitness of things, let me remind you, the Association has of late years adapted itself: for, when we last assembled here, this Section, of which I am proud to have been the founder, had no existence.

When in 1838 I here took a retrospective view of the progress made by the British Association in the first seven years of its existence, it was natural that, with the strong desire with which I was imbued, I should have then expressed my regret that Geography had not hitherto received at our Meetings that amount of attention to which it is justly entitled. Referring to the progress then made by the Royal Geographical Society of London, when its members were a third part only of the present number, I expressed a hope that the great geographical problems which had been lately solved, and which remained to be worked out, might be brought regularly before the Association, and secure the application of some of those funds which had hitherto been exclusively appropriated to the advancement of other sciences.

Steadily pursuing this idea, it was therefore a great satisfaction to me to succeed, after an interval of sixteen years, in establishing in the year 1854 this separate Section of Geography and Ethnology; and since that day I can truly say that this department of our Scientific Body has been most popular, and at the same time, I trust, eminently useful.

Under these encouraging aspects, I will first call your attention to some of the

leading geographical results in British Geography which have been brought about since we last met here. At that time four years had elapsed since (at our first Meeting in Scotland) I directed the attention of this Association to the untoward condition of the Topographical Survey of the British Isles, by showing that no map of any country north of the Trent was in existence; in short, that all the North of England and the whole of Scotland were in that lamentable state; whilst the survey of France, and of nearly all the States of Germany, had been completed. Having roused public sentiment to this neglected state of the national map—so neglected, indeed, that one of the great headlands (Cape Wrath) was known to have been laid down some miles out of its proper place in all maps and charts—deputations to the Government followed, in the first of which I pleaded the cause of Geography, but with little or no effect as regarded the North of England and my native country, Scotland. Ireland then absorbed nearly all the labours of the Ordnance Survey, and was at length furnished with a map on the six-inch scale, from which the really useful general map on the one-inch scale has since been constructing, but is not yet completed.

In the twenty-nine years which have elapsed since the period when the question was first agitated, at Edinburgh, considerable progress has doubtless been made; but it is surely a reproach to a powerful country like Britain that in thirty years we have only just seen the region between the Trent and the Tyne delineated and laid down on a real map, *i. e.*, on the one-inch scale; whilst even yet the maps of the northernmost English counties are unfinished.

In making this observation, I am well aware that the skilful officer, Colonel Sir Henry James, who now directs the Survey, has made every exertion to complete this national object, and has shown great talent in its management. The tardy execution of the work has been due to two causes. The first of these was the deviation from the original plan of operations, which I greatly regretted, and from which on various occasions I have entered my humble dissent. The construction of a General Map of Great Britain, on the scale of one inch to the mile, was in rapid progress some thirty years back; and had this been followed out to its completion, in the first instance, without applying the Survey forces to other and more detailed objects, not merely England, but the whole of the British Isles would have been completely mapped many years ago, and upon a scale larger than that used in the general map of any other country; in fact, upon the largest scale to which the term "map" can be applied, or which can really serve some of the most essential purposes. The first deviation from the early plan took place in Ireland, where, in order to settle disputes relating to property between townlands, the six-inch scale was introduced. Now, plans on this scale, if not furnished with contour lines, do not embrace the salient features of a true map, whilst the dimensions of the sheets relating to any one county are so large, that though highly useful to geological surveyors and miners, they cannot be consulted for improvements of roads, construction of canals, railroads, or other public works, still less for any general military movements or travelling purposes. With the extension of the Survey to the North of England and Scotland, not only has the six-inch scale been adopted, but much larger cadastral plans, on the $25\frac{1}{2}$-inch scale, have been and are in execution. While these plans are, I grant, most valuable to individual proprietors, they are beside the purposes of the geographer, inasmuch as they exhibit no attempt whatever at the delineation of physical features. Hence I regret that their execution should have been preferred to the completion, in the first instance, of an intelligible and useful Map of the British Isles, which, if made to depend on the previous completion of the large-scale plans, will still involve, I fear, the lapse of another very long period before the whole country will possess what geographers consider a map. The other and the most powerful cause which has retarded the progress of good cartography has been the frequently recurring cold fits of indifference and consequent cutting off of the supplies by which our legislature has been periodically affected, and which have necessarily occasioned a collapse and stagnation in the works of this important Survey.

As respects my own special department, or the "Geological Survey," I deprecate still more strongly the delay of the construction of the one-inch Map, seeing that no geologist can yet labour effectively in the Highlands of Scotland, and accurately

delineate their interesting rock-formations by colouring any one of the defective county maps of that region. With my expression of regret on these points, I am bound to declare that the large cadastral plans are admirably executed; and that for the registration of property they are of material value. As such great landmarks, they will always be mementos of the highly useful services of Sir Henry James and his associates.

Let us now cast a rapid glance over the progress of discovery in distant lands, and particularly where our countrymen have signalized themselves. In this wide field wherein our knowledge has been extraordinarily increased within the last few years, I will limit my remarks to three or four regions; the more so as I have recently addressed the Royal Geographical Society at large on many collateral topics in a Discourse which is now in circulation.

Australia, scarcely known to the civilized world till after Cook's voyages (1770–75), has of late been so rapidly colonized by Britain, that ere long she will be no mean rival of those vast regions of North America which were first occupied by subjects of the British Crown. At former Meetings of this Association we have dwelt on the early discoveries of new lands in the interior of Australia, in which the names of Mitchell, Eyre, Sturt, Leichardt, and others have been always mentioned with honour and respect. The later journeys of the brothers Augustus and Frank Gregory have earned for those good surveyors the highest honours of the Royal Geographical Society, for their extensive researches and determinations of longitude and latitude in Northern, Eastern, and Western Australia. Whilst more recently the bold expedition of Burke and Wills cost those noble fellows their lives, the latest researches of their successors stand out as indeed most singularly successful. M'Douall Stuart, after various previous triumphs, in one of which he reached the watershed of North Australia, has actually passed from Adelaide, in South Australia, to Van Diemen Bay on the north coast, in latitude 15° S. Contemporaneously with this last expedition, M'Kinlay, proceeding also from Adelaide, reached the Gulf of Carpentaria, and thence travelled to the eastern shore; and Landsborough, realizing all the value of the discoveries of Burke and Wills, and penetrating from the Gulf of Carpentaria, traversed the continent southward until he regained the noble colony of Victoria, in which the expedition was organized. As I have recently dwelt at some length on these bold adventurers in my Anniversary Address, referring also to some geographical determinations by Mr. Walker, of Queensland, I will now simply direct your attention to the huge map of Australia which hangs upon the wall, and on which all the routes of these explorers are laid down.

The rapid rise of the different Colonies in Australia is truly marvellous; and, whilst we have successfully occupied all the available ports and lands along the eastern, southern, and western sides of the great Continent, we are now, I rejoice to say, beginning to extend our settlements to the north coast, the occupation of which I have advocated for many a year, on political as well as on commercial and colonial grounds. A few years only of practical researches have dispelled our ignorance respecting the interior of this vast mass of land, in which, though there are wild desert tracts, there are also many rich and well-watered oases of fine pasture-grounds, through which the colonist may open out communications across the Continent from the south and east to the northern shores. A short time only, I venture to predict, will elapse before towns shall arise at the head of the Gulf of Carpentaria, as well as at the mouth of the Victoria River of the North, from whence, as well as from the new settlement of Cape York, Australians will have a direct communication with our great Indian Empire. In speaking of the progress of these remarkable Colonies, it may be considered invidious to seem to select any one for special notice, where all of them have such high claims to our notice. I may, however, in passing, mention the last-formed of these wonderful separate Governments. This is Queensland, possessing a surface six times greater than that of the United Kingdom, and the very grazing-grounds of which (according to its accomplished Governor, Sir G. Bowen) are about twice as large as the British Isles, including large tracts peculiarly adapted to the growth of cotton.

Nor can I omit to notice the striking encouragement given to geographical exploration, and, indeed, to the cultivation of many branches of science, by Governor

Sir Henry Barkly, whose final Address to the Royal Society of Victoria is one of which the President of any Scientific Society in Europe might well be proud.

The progress which our enterprising Australian Colonists have made, not only in wealth and material prosperity, but in all that can dignify a people, was strikingly manifested at the last Great International Exhibition. In it we saw collocated, not merely the rich natural products of gold and copper, with admirable pictorial views which even enabled us to imagine that we had visited the mines of our antipodes, but we also had before us solid proofs, in the publication of excellent Maps and the Catalogues of the valuable Libraries of Sydney and Melbourne, that there is scarcely any branch of knowledge or of industry which is not cultivated in Australia with a zeal rivalling that of the mother-country.

Relying on the conversations which it was my privilege to hold with the distinguished men who represented the several Australian Colonies on that occasion, as well as with many personal friends who have long resided there, I feel assured that there is no part of the British dominions where the people are more attached to the Sovereign and the British Constitution than Australia. It has always, therefore, been a source of pain to me, when some persons have spoken or written of the coming of the day when these great Colonies are to be separated from us. Seeing no cause for such separation, and believing that our Government and Legislature are much too enlightened to commit the error into which our Government fell when Britain lost her North American settlements, we are, I rest satisfied, never likely to estrange our Australian Colonies by similar treatment. It has been well said by a late Governor of South Australia that the loyalty of Australia is an homage to the enlightened rule of England, of which her statesmen may be proud *. On my own part, I am indeed persuaded that, if judiciously and considerately treated, Australia, which affords by far the finest possible field for the emigration of our superabundant population, will long continue to be a source of wealth and strength to the mother-country; and will, I trust, for ages hold out a proof that the people who live under a constitutional monarchy enjoy much truer freedom, in its best sense, than those who have formed part of any democracy, ancient or modern.

And now let me say a few words on the last grand geographical feat—the discovery of the water-basin which supplies the Nile.

The first act in this portentous operation was the discovery, by Captain Speke (when he left his leader, Captain Burton), of the large African lake which, in the year 1858, he named Victoria Nyanza. In his late expedition, when accompanied by Captain Grant, he has proved (as he said he would before he started) that this great body of fresh water is the main source of the White Nile; and in this exploit we have one of the greatest geographical triumphs of all history. For age after age had rolled on—traveller after traveller, from the days of the Egyptian priests and of the Roman emperors down to modern periods, had endeavoured to ascend the Nile to its sources, and all had failed! By reversing the line of research followed by all former travellers, and by proceeding from the east coast of Africa, near Zanzibar, to the central, lofty, and flat plateau-land forming in that meridian the watershed between North and South Africa, these gallant Indian Captains reached the great reservoir from whence the Nile flows. Thence they traced the mighty stream northwards into Egypt, and demonstrated that, whilst the White Nile, which they followed, is the Great Nile; the so-called Blue River, joining the parent stream at Khartum on the frontiers of Egypt, is, like the Atbara and other waters, a tributary only.

As the outlines of the long walk of Speke and Grant across those vast interior and equatorial regions of Africa have been given to the public, first in my Address to the Royal Geographical Society, and subsequently in various periodicals, it would be out of place to say more on the subject until their own full account, which they are preparing with many illustrative sketches, shall have been published.

In the mean time it is gratifying to know that our gracious Queen has shown by her own kind expressions how truly she is proud that two of her own gallant Officers should have succeeded in performing what the people of many a European

* See the Lecture, "Australia: what it is and what it may be," by Sir Richard G. MacDonnell, C.B. Dublin, 1863.

nation have failed to accomplish. We may therefore be sure that the British people will rejoice with all geographers, if the travellers should receive due honours and rewards for such glorious services.

Among foreign Sovereigns the King of Italy has taken the lead in the desire to commemorate the great event, by ordering two gold medals to be struck on the occasion. The first, which immediately after its completion was presented to the leader on the Royal Geographical Society's Anniversary, had on its reverse the words, so well known to Englishmen as the motto of Nelson, "Honor a Nilo." The second, which the Italian Minister, the Marquis d'Azeglio, since put into my hands, and which has been delivered by me to Captain Grant, has on it these pregnant words: "Al Capitano Grant: divise col Capitano Speke gloria e pericoli." Thus do these medals remind us that, through the enterprise of her sons, England has won glory through many a danger at the sources, as at the mouth, of the Nile.

Among the geographical communications which have been already sent in to be read at this Meeting, and of which I have any acquaintance, I will now allude to four only.

Referring still to Africa, we hope to be favoured by Dr. Barth with a translation from the German of the ascent of the lofty snow-clad mountain of Kilimandjaro, in tropical Eastern Africa, as carried out by that energetic Hanoverian traveller, Baron C. von der Decken.

In relation to China, you will, I doubt not, be much gratified with the memoir of Mr. R. Swinhoe, a practised Chinese scholar, and formerly a British Vice-Consul, on the large, but little known, island of Formosa, and the numerous islets between it and the mainland. Whilst the publications of the last few years, including the 'Narrative of the North China Campaign of 1860'*, by Mr. Swinhoe himself, have rendered us well acquainted with large portions of the interior of China—and whilst Captain Blakiston has laid down on a beautiful chart the course of that mighty stream the Yang-tsze-Kiang, to a distance of nearly 1000 miles above the highest point previously reached by our countrymen—the great island of Formosa, off the eastern coast of the Chinese mainland, has remained comparatively unknown. Since the days when parts of its west coast were surveyed, the outline of those shores has, it appears, undergone a great change by the rapid increment of silt and sand washed down from the mountainous interior; so that a new survey is imperiously called for, to render some of the ports accessible to commerce. Near the north end of the island, indeed, the port of Tam Sui is not liable to these dangers, and is indicated by Mr. Swinhoe as being best suited for commercial dealings; and this part of the coast was so well surveyed by Captain (now Admiral) Collinson, that his charts thereof may be entirely depended on. In short, now that Lord Elgin's Treaty of Pekin has thrown open to British enterprise all the ports of China, it is to be hoped that, by the completion of accurate surveys of the south-western coast of Formosa, its present unapproachable harbours will soon be frequented by British vessels. We learn that these extensive lands are very rich in natural productions; and Mr. Swinhoe will interest you much by a description of the habits, costumes, and peculiarities of the Chinese inhabitants. The aborigines —a Malayan race—still occupy all the mountainous districts, or eastern side of the island, and live among the great forests that yield so much camphor. The subject of Formosa is so novel that this communication will prove very attractive; whilst you will, I doubt not, be struck by the coloured drawings which the author has made of the Chinese occupants of this great island, and after whom, particularly the women, the Portuguese may well be supposed to have named it "Formosa." If, as I have been led to believe, my accomplished friend Sir Harry Parkes should join our Section on this occasion, it is certain that he will give us a lively and accurate description of the Chinese people, as well as a solid and trustworthy account of our political and commercial relations both with China and Japan.

Turning to Central America, you will have a very interesting memoir by Mr. Osbert Salvin on the physical geography of Guatemala, in which the author will particularly notice the geographical distribution of the various zoological productions of that country. He will also give us accounts of its virgin forests, volcanos,

* London: Smith and Elder, 1861.

and lakes, as well as of the Indian remains and buildings which he has traced in it.

Another American subject to be brought before us will doubtless bring to our halls many persons interested in the triumphs of mechanical skill when practically applied to the overcoming of great difficulties presented by physico-geographical features. Mr. William Wheelwright has commenced the execution of a stupendous engineering work, called the Great Central Argentine Railroad, to which he formerly called the attention of the Royal Geographical Society, and which is destined to connect the great port of Buenos Ayres, on the Atlantic, with the city of Copiapo and the port of Caldera, on the Pacific. From the Pass of San Francisco in the Andes (16,000 feet high), it will descend the western side of those mountains through the valley of Paipote, and reach the city of Copiapo, 1300 feet above the ocean; thence continuing to Caldera, one of the finest ports in the Pacific, after a descent of 246 miles from the culminating point of the road in the Andes. With the exception of one inclined plane of five or six miles, the immense elevation is to be traversed by locomotive engines; for Mr. Wheelwright has already had a railroad constructed from the valley of Copiapo to the mineral district of Charmacillo, on which the trains run twelve miles an hour, in ascending 1900 feet in nine miles!—a gradient unheard of, I believe, in Europe.

In the commencement of this Address I spoke of the imperfect means we possessed in 1838 of reaching rapidly this flourishing town by rail; and still less then had the genius and sagacity of Wheatstone overspread the countries with the electric telegraph. Such however has been the progress, that in 1861, at Manchester, we interchanged questions and answers with the philosophers of St. Petersburg during an evening assembly; and advances have been effected for transmitting telegrams round the world. A vast stride will be made in the ensuing winter by the extension of the telegraph from Constantinople through Asia Minor, and thence *viâ* the Persian Gulf to the country of Mekran, at the head of the Indian Ocean, and so to the British possessions in India. The preliminary researches which have been made towards the establishment of this overland electric line to British India have, indeed, already laid open to us countries which, though unknown to the moderns, were seats of power when Alexander the Great and his lieutenants invaded India. At the same time other efforts are in progress to carry a system of telegraphs from Russia through Siberia, and thence across the Desert of Gobi to Pekin.

The great desideratum, however, of connecting Europe with America by a Submarine Telegraph remains to be accomplished. With a view to that desirable end, the Council of the Royal Geographical Society warmly supported a proposal by Dr. Wallich to effect a complete survey of the intervening sea-bottom as a precursor to the actual laying down of a cable upon the vast unknown irregularities of the submarine surface; such an effort being certain to throw much light on Natural History and Physical Geography. The soundings which ascertain the nature of the bottom of the ocean, not only give us the outlines and characters of various sunken rocks, sands, and mud-banks, and of vast and deep cavities, but inform us where the under-currents prevail, and where at vast depths the surface is tranquil and unruffled in some places, whilst in others submarine volcanos disturb the sea-bottom. Nay more, these submarine operations have taught us that some of the lower animals cannot only live, but flourish, preserving even their colours, at the enormous depth of one mile and a half. We thus see how the efforts of the nautical surveyors and the engineers to spread the electric telegraph are not merely destined to be useful to mankind, but also to elicit great and important truths in Natural History, the development of which is specially connected with the pursuits of the geographer.

In adverting to the consideration of the other science which this Section embraces, it gives me pleasure to be able to report that the Ethnological Society is in a prosperous and satisfactory state, having within the last three years greatly increased the number of its members and improved its financial condition. This satisfactory result is in great measure due to the vigorous exertions and numerous contributions of my eminent friend, its last President, Mr. John Crawfurd, whom I am happy to see among us at this Meeting. Under his auspices the Ethnological Society brought out last year a volume of Transactions, forming the first of a new

series, which has been favourably received by the public, and a second volume has just been published. As the Ethnological Society has had the good fortune to see the place vacated by the retirement of Mr. Crawfurd filled up by the appointment of so skilful and philosophic a naturalist as Mr. John Lubbock, and as Mr. Francis Galton, the President of this Section at the last Meeting of the Association, has kindly consented to act as our Ethnological Secretary, we may reasonably calculate on receiving much sound support from men like these, who can so well connect the sciences which we cultivate with many other branches of human knowledge.

In conclusion, I have now only to exhort you to profit by this Meeting, not merely by listening attentively to the reading of the various memoirs to be brought before you, with many of which (particularly those relating to Ethnology) I am as yet unacquainted, but also by discussing all doubtful points in a fair spirit of inquiry. Above all, let us strive to show, by the amount of useful knowledge we gather together, that the value and interest attached to the proceedings of this Section are as effectively sustained on the banks of the Tyne as they have been at any other meeting-place of this our Parliament of Science.

On some Curiosities of Physical Geography in the Ionian Isles.
By Professor Ansted, *F.R.S.*

The Ionian Islands and the mainland of Greece abound with matters of interest to the geographer. Among them are:—1. Valleys and circular depressions receiving drainage, but without apparent outlet. These abound in Corfu, Santa Maura, and Cephalonia. They occur also in Zante, rendering the islands less healthy than they would otherwise be. They are, beyond doubt, results of the peculiarly cracked and open condition of the limestone-rock of which the whole of the islands may be said to be made up. 2. Inflowing currents of sea-water. Very clearly connected with the same condition of the rock is the curious phenomenon presented near the town of Argostoli, the capital of Cephalonia. The town is on a low step of cracked and cavernous limestone, a foot or two above the highest ordinary level of the sea, on one shore of a small creek, separated by a higher ridge of similar limestone from the Gulf of Argostoli. There is hardly more than a few inches perceptible tide in the eastern part of the Mediterranean, and even in this creek the rise, though multiplied, is small. At four places close to the town there are inlets or cracks, a few feet wide, entering some hundred yards into the land, and terminating in broken, rocky, cavernous spaces. Instead of the ordinary phenomenon of the fresh water running over the land to the sea, we have here the reversed phenomenon of the sea coming in by these crevices, running for some distance over the land, and finally entering and becoming lost in the earth. It is nothing unusual in limestone-countries to find water disappearing into the earth; but it is certainly exceptionable that this should be sea-water, and that it should continue permanently. The author suggested as a better explanation of these inflowing currents than has yet been given, that they are probably results of the cracked condition of the limestone-rock and the great evaporation from the surface during summer. It is not unusual to see the vine—especially the grape-vine—growing and flourishing on piles of loose, angular limestone, without the smallest particle of visible soil. The moisture required by the roots is no doubt supplied by constant evaporation from the water underground. It goes on so long as there is any moisture left, and the hotter and drier the limestone at the surface, the more readily is the supply sucked up. Thus, whatever water enters the rock from rain falling on the surface, and all that comes in by these entering currents from the sea, is probably exhausted by evaporation from the surface. It would follow, if this explanation be correct, that a deposit of salt must be forming in connexion with the limestone into which the water penetrates.

On some Points in the Cranioscopy of South American Nations.
By C. Carter Blake, *F.G.S., F.A.S.L.*

The object of the paper was to reconsider some of the primary principles on which those cranioscopists who have classified the races of South America have based their arrangements, and to call especial attention to a few important excep-

tions which appear to invalidate the generalizations commonly accepted. Every practical cranioscopist is aware that Retzius's classification of human skulls into brachycephalic and dolichocephalic was applied by that illustrious Swede to the arrangement of the great leading South American types. The lamented and deceased cranioscopist gave, as examples of the brachycephalic type, as exhibited in South America, the tribes of Ecuador, Peru, Bolivia, Chile, La Plata, Patagonia, and Tierra del Fuego; while the dolichocephalic or long-headed type found its representatives in the populations of Carib, Guarani, Brazilian, Paraguay, and Uruguay origin. This broad generalized statement of facts still remains the accepted and predominant hypothesis. How far is it consonant with the extent of our knowledge on the subject? Those few tribes and nations of South America of which any accurate and reliable information exists will be briefly recapitulated in the following observations, and especial attention drawn to the *desiderata* which appear in our collections. The geographical order will be adhered to, apart from any broad generalization which may arise, based on craniometrical classification; such generalizations, *e. g.*, as that of Morton, who divided the whole American races into two great families; the Toltecan, comprising the extinct half-civilized tribes which have become extinct during a prehistoric period; and the barbarous tribes. The latter division was subordinated amongst the Appalachian, Brazilian, Patagonian, and Fuegian branches. Mr. Blake then proceeded to criticise these types in detail. In the first place, he pointed to Colombia; the characteristic type prevailing amongst the tribes of Venezuela is the Carib. The skull is here markedly long-headed, with the parietal diameter less than the longitudinal. The frontal bones are strongly flattened; the zygomatic arches large. Accurate and reliable evidence respecting the cranial conformation of the natives of Ecuador is wanting. The Cara and the Scyri are unknown. There were several types in Peru; *e. g.* the Chincha type, short-headed; the Chimú type, long-headed, so far as known; the Inca or Quichua, short-headed, flattened from before to behind by compression from the frontal bone to the occiput. In Bolivia there were the Aymará, long-headed, of which few examples existed in our collections; the Titicacan, long-headed, but of whom the other physical characters are unknown. In Chile, at the present day, the type was long-headed, so far as known. The Anthropological Society of Paris has recently prepared a series of queries respecting the physical characters of the Chile races, which showed the utter want of information on this topic. In Patagonia the type was also long-headed, as in Tierra del Fuego, Paraguay, La Plata, and Brazil.

On Celtic Languages. By R. S. Charnock.

The author commenced by stating that, having had an opportunity of reading Mr. Crawfurd's paper before attending the Meetings of the Association, he should reply to it in detail. Mr. Crawfurd stated that when between two or more languages there was a substantial phonetic or grammatical agreement, they might be pronounced cognate. In the next paragraph, however, he laid down a different proposition, namely, that the words which most distinctly proved languages to be cognate were conjunctions, &c., words, in fact, which could not be constructed. He would not quarrel with Mr. Crawfurd for using the term German in describing the origin of five-sixths of our English language, when doubtless Anglo-Saxon was intended. The Norman element, instead of being one-sixth, probably did not constitute a fiftieth part of the language. On the question of grammatical structure, he combated the notion that the leading languages of Europe, ancient and modern, had all sprung out of a dead language of India, and also the proposition that the Siamese was a monosyllabic language, and contended that race could never to a certainty be determined by language. It would be considered absurd in a man who, having given cogent reasons for not visiting Rome, forthwith started for the Holy City. But Mr. Crawfurd, after going to the trouble of arguing that the boasted test of agreement in the mere structural form of language is inadmissible, proceeded nevertheless to compare the Gaelic and Welsh, with the view of showing that in point of structure they were entirely different languages. Again, after stating that the formation of compound words by the help of prepositions was a distinguishing characteristic of Indo-Germanic or Aryan languages, and, amongst

them, of the Sanskrit, the Gaelic, and Welsh, Mr. Crawfurd argued that no such manner of compounding words was known to either of these languages. This assertion was inexcusable; for if he had searched the dictionaries of the last two languages, he would soon have found that in upwards of one-third of the words the first syllable was a prefix. The author quoted numerous instances to prove this; and then contended that the English language was not of German origin, but a language which was principally based upon Greek and Latin, derived partly through Saxon and Norman-French, and partly direct from the two former languages.

On a Visit to Dahomey. *By* Mr. Craft.

On the Commixture of the Races of Man, as affecting the Progress of Civilization in Eastern Asia and the Malay and Polynesian Islands. *By* John Crawfurd, *F.R.S.*

The writer gives, as examples, the mixture of the Chinese with the Malay, of the European with the Malay, and of the European with the Polynesian. The first description of admixture forms the largest portion of the so-called Chinese inhabitants of the Philippines with the Malayan Archipelago; the second, under the designation of Mesizo, a considerable body in the Philippine Islands; and of the third, a striking instance is to be found in the Pitcairn Islanders.

On the Origin of the Gipsies. *By* John Crawfurd, *F.R.S.*

The gipsies, whose first appearance in Europe took place 400 years ago, or about seventy years before the discovery of America, have excited much curiosity for the last fifty years, in consequence chiefly of their being believed to be Hindus—an hypothesis, according to the writer of this paper, for which there is no other evidence than a few Indian words in their rude language, and a somewhat darker complexion than that of the people they are living among. Of the genuine Hindu words in their language he gives a list amounting to more than 123, while of other oriental languages, such as Persian, Turkish, and Arabic, it contains a considerable number. "From all," says he, "that has been said in the course of this paper, I must come to the conclusion that the gipsies, when, above four centuries ago, they first appeared in Western Europe, were already composed of a mixture of many different races, and that the present gipsies are still more mongrel. In the Asiatic portion of their lineage, there is probably a small infusion of Hindu blood; but this is, I think, the utmost that can be predicated of their Indian pedigree. Shortly speaking, they are no more Hindus in lineage than they are Persians, Turks, or Europeans; for they are a mixture of all these, and this in proportions impossible to ascertain."

On the so-called Celtic Languages, in reference to the Question of Race. *By* John Crawfurd, *F.R.S.*

The object of this paper is to show that the Welsh and Armorican languages on the one side, and the Irish and Scots-Gaelic on the other, are not sister tongues, but distinct languages, and hence that the people speaking them, in so far as language can be considered evidence, are of different races. This the author endeavours to show by an analysis of the grammatical structures and vocabularies of the two tongues. "If," says he "the facts and arguments adduced in the course of this paper be valid, the languages which are its subject are two distinct and separate tongues. Bede, indeed, seven centuries ago, pronounced the Welsh and Irish to be as different from each other as Latin and Saxon. In so far, then, as language can be considered a test of race, and to the extent that one European race differs from another, the parties speaking the two languages must be viewed as distinct original races." "If," he concludes, "the Gaelic language on the one hand, and the Welsh and Armoric on the other, be two distinct tongues, and not, as the denomination of Celtic would give us to understand, dialects of a

common tongue, it will of course follow that the people speaking the Gaelic language, whether of Ireland or of Scotland, had no share in the great enterprises of the people known to the Romans as Gauls. The people who established themselves in Northern Italy, who captured Rome, overran and plundered Greece, and, under the name of Galatians, established themselves in Asia Minor, were the Celts—men who spoke the same language which is now spoken in Wales and Brittany, although it is not likely that the inhabitants of these poor and remote countries had any share in these remoter enterprises."

A few Notes on Sir Charles Lyell's '*Antiquity of Man.*' *By* John Crawfurd, *F.R.S.*

The author agrees entirely with Sir Charles Lyell in his conclusion that the existence of the human race is of a far higher antiquity than is popularly believed, and he dissents from him only on the question of the commutation of species, confining himself here to Sir Charles's arguments drawn from language and the imagined transition of the family of the apes into man, and hence the unity of mankind. On the subject of language, Sir Charles Lyell, adopting the Aryan or Indo-Germanic theory as expounded by Professor Max Müller, gives it as his opinion that no language has been known to have endured beyond 1000 years; and in opposition to this opinion, the author of the paper quotes the Arabic, which, dating from the publication of the Koran to the present time, has lasted for 1240 years, while the Greek language, reckoning from the time of Homer to our own days, has endured, with small change, for 2600 years; he further adds that, when there is no change in the frame of society, as among the Australians, a language may last even for thousands of years. On the question of the transmutation of the apes into man, Sir Charles Lyell adopts the opinions of the learned and ingenious Professor Huxley, who, while he adopts the theory that man is a direct transition from the anthropoid monkeys, takes special pains to guard himself from concluding that there is any other than a certain structural resemblance between them. "Let me, then, take this opportunity," says he, "of distinctly asserting that the differences are great and significant; that every bone of a Gorilla bears marks by which it may be distinguished from the corresponding bones of a man; and that in the present creation, at any rate, no intermediate link bridges over the gap between *Homo* and *Troglodytes*. At the same time, no one is more strongly convinced than I am of the vastness of the gulf between civilized man and the brutes, or is more certain that, whether *from* them or not, he is assuredly not *of* them. No one is less disposed to think lightly of the present dignity, or despairingly of the future hopes, of the only consciously intelligent denizen of this world." "The monkeys, then," concludes the author of the paper, "have an outward and even a structural resemblance to man beyond all other animals, and that is all; but why nature has bestowed upon them this similarity is a mystery beyond our understanding."

On a Human Cranium from Amiens. By Henry Duckworth, *F.G.S.*

This was a short communication relating to the discovery of a human skull, in the summer of 1861, whilst on a visit to the quarries of St. Acheul. It was obtained from the deposit known to the workmen as the "Découvert" bed, its depth from the surface being about six feet.

Ethnology of Eastern Mantchuria. By Captain Fleming.

From Tientsin (North China) to the Capital of Mantchu Tartary. By Captain G. Fleming.

The paper described a journey performed by the author in company with Mr. Meakin in 1861. The travellers did not adopt the Chinese dress, as they were advised to do, believing that it was not only difficult to maintain the disguise—the discovery of which might lead to consequences of a very serious nature—but that they would consult their own safety, and produce a good impression in the

natives, by appearing in the English costume, and making no secret of the object of their journey. The explorers passed the Great Wall of China, from which they extracted a brick (which was exhibited), and gleaned much valuable information about the country.

On the Discovery of the Sources of the Nile. By J. A. GRANT, *Bengal Army.*

Our party consisted of Captain Speke, myself, and two hundred natives, formed of Seedees from Zanzibar, ten men of the Cape Mounted Rifles, and negro porters returning to their homes in the interior. Of baggage-animals, we had twelve mules and three or four donkeys; but these all died within three months of our having left the coast. Food was purchased, and porters paid, in cotton cloths, Venetian beads, or thick brass and copper wire; when these failed, the chiefs of the countries were conciliated with presents of rifles, ammunition, watches, medicines, &c.

The route from the sea to the lake district lay through large properties governed by paltry but independent sultans, who delayed us till their demands for taxes were satisfied. Further on a new and distinct race were met with—the Wahuma kings owning the fertile lands on the western shores of the Lake Victoria-Nyanza, and holding the key to the Nile. Fortunately for us, they showed great intelligence, asking many questions about our Queen, our arts and manufactures, and finally granted our long-wished-for desire—a passage through their countries towards Egypt. On questioning them where the waters of that mighty lake of 2000 square miles went to, they were, until enlightened by us, as ignorant of its course as we had been, for ages, of its source.

On the Aboriginal Occupation of North Tynedale and Western Northumberland: an Illustration of the Social Life of the Northumbrian Celts. By the Rev. G. R. HALL.

The author said that his archæological survey had extended over an area of about 300 square miles, and that many vestiges of the prehistoric period were now noticed for the first time. The numerous ancient British *Cærau*, or fortified towns, might be considered as hill-forts, located, as the Warden Hill Camp, near the confluence of the North and South Tyne, on elevated sites; or, as lowland fastnesses, of which the Countess Park Camp is a good type, occupying escarpments, usually flanked by deep ravines in the river-basin itself. The foundations of ramparts, including from one to three acres, and of numerous hut-circles or dwellings, ranging from 15 to 46 feet in diameter, can be traced in many instances. The action of fire was evident on the unhewn, massive blocks of white freestone in several *oppida*—a proof of long occupation by the aboriginal tribes, who seem to have consisted of petty septs or clans, generally at war with one another. Numerous terraces for primitive cultivation, querns or hand-mills, large mounds of iron scoriæ, with the rudest pottery intermingled, and "delves" to furnish ore for these primitive smelting-works, occur at Birtley and elsewhere. A remarkable conical tumulus, 30 feet high and 100 paces in circumference, exists near Gunnerton, called the Money Hill. Many smaller barrows, in one of which a *cist-vaen* was found, have been noticed, and several flint arrow-heads and iron spear-heads have been ploughed up in this district.

These vestiges were shown to be most probably Celtic, and of pre-Roman date, the present state of the North-American Indians illustrating very nearly the social life of the Gadeni Celts.

On Routes between India and China. By Captain HENDERSON.

The paper treated of some proposed overland and river routes between British India and Western China for emigration and trade. These routes are to be opened out by the general system of tug- and tow-boats of the native type, to be established in Eastern Bengal and British Burmah, and have for their object to open the coal-fields of Assam and Silhet in connexion with the Eastern Bengal Railway, and to extend the traffic of the Calcutta and South-eastern Railway to Burmah and China, *viâ* the River Irawaddy and its tributaries at Bamú, under the recent

treaty with the King of Burmah. The author stated that the large consumption and continual exhaustion of coal in England and America had induced him to bring before them the coal-supply of India, which at the present juncture was a question of vital importance as to the financial position of our railways there—Sir Charles Wood having recently guaranteed the East Indian Auxiliary Railway for the provision of cheap coal from the Kurhurballee fields south of the Ganges, while the working of the Assam coal-fields is a matter of greater moment, as it would facilitate the project of overland communication between Western China and British India, and not only extend trade, but induce emigration to eastern Bengal and British Burmah, which provinces have an area of nearly 200,000 square miles, and a population less than 4,000,000. The Oriental Inland Company, after spending a large portion of their capital in trials, now admitted that the train-system was a failure. The author had persevered in experiments to render his system a perfect one, and some recent improvements in boilers and condensers would enable him to establish a cheap mode of transit by tug- and tow-boats of native type. The paper was accompanied by appendices and diagrams explanatory of the nautilus-flotilla system of boats advocated by the author; and it stated that by their adoption Assam coal could be brought to Kooshtee at two-thirds of the present price of that brought from Calcutta, and at one-fourth of its cost in the upper part of the Burhampooter.

On his Exploration of certain Affluents of the Nile. By Baron von HEUGLIN.

On some Old Maps of Africa, placing the Central Equatorial Lakes (especially Nyanza and Tanganyika) nearly in their true positions. By JOHN HOGG, *M.A., F.R.S., F.R.G.S., &c.*

The author described in this paper some old maps of Africa, in each of which *one* of the central lakes of Equatorial Africa is laid down nearly in its exact position.

The *first* of the maps mentioned is one of the 16th century, which is preserved, according to Sir R. I. Murchison, in the College de Propagandâ Fide at Rome. In it the Nile is delineated as flowing out of an equatorial lake; and it was probably in part derived from that by Diafar Ben Musa in A.D. 833.

In this Arabic map the Nile is laid down as issuing from a lake upon the equator, named *Kura Kavar*.

The next map is that of Africa, by John Senex, F.R.S., Geographer to Queen Anne, and which he dedicated to "Sir Isaac Newton, Kt., President of the Royal Society, and Master of Her Majesty's Mint," about 150 years ago.

In it is placed, in about 1° of latitude from the equator, southwards, a large lake of much the same *form* as the Lake *Nyanza*, and extending to near 3° south lat. The 35th meridian of east longitude intersects about one-third of its west portion, instead of dividing it at about one-third of its east side. Senex says, "This great lake is placed there by the report of the negroes." But the same able cartographer has placed, in his 'Map of the World,' the "great lake (*Nyanza*), by report of the Caffres," *nearer* to the equator, and in about 33° east long., which is a much *more accurate* position than that given in his former map.

The fifth map of Africa is a small one, published in 1811, by Walker, in his 'Universal Atlas.' This, omitting the former equatorial lake, or the *Nyanza*, exhibits a very long and narrow lake, called "Lake of Zambre." It presents, upon the whole, much of the *shape* of the Lake *Tanganyika*, its north extremity being placed at about 3° of south lat., and its east position in the meridian of 31° (or nearly so) of east long. It will be seen that Walker has only misplaced the Lake Zambre, or *Tanganyika*, by *one* degree of longitude—a singular coincidence, when we remember the date of its execution, more than fifty years since.

Another lake, the *Maravi*, or Nyassa, called by some *Zambesi*, is given in a sixth map, also exhibited, which is by Lizars, at Edinburgh, in 1815; but with remarkable carelessness, or probably scepticism, it omits altogether the *two* former great equatorial lakes.

Hence, inasmuch as each of these *three* maps only places a *single* and a different

lake, it is necessary to have all the *three* to constitute a more accurate map of that portion of Africa.

Next, Mr. Hogg showed that the best geographers, including Herodotus and Ptolemy, considered the *White* river, or the *western* branch, as the *true* Nile. And he then produced two more ancient maps, taken from two early Latin translations and editions of the latter geographer, wherein the "Nili Paludes," or lakes, with the Mountains of the *Moon* (Montes *Lunæ*) as their origin, are differently laid down: one was published at Rome, with an atlas, in A.D. 1478, and the other at Bâle in 1542. The earliest of these two maps represents a *third* large branch of the Nile, which it calls "Astapus fluvius," flowing from the S.E., and having its source in a small lake, which is bisected by the equinoctial line. Under this is written "Coloa Palus." Since the Lake Coloa, or *Caloë*, is clearly identified with the lake now termed *Dembea*, this river must answer to the *Bahr el Azrek*, the Azure or *Blue River*; its geographical position, therefore, is assigned far too much to the south.

Mr. Hogg also described Seneca's account of the two officers sent by Nero Cæsar to find out the "Caput Nili," and which was narrated by them in the presence of that contemporary writer; and he conceived that the Nile which those officers explored was the *west* branch, or *Bahr el Abiad*, by reason of the vast quantity of "implicitæ aquis herbæ" still existing there and in the *Bahr el Ghazal*; and he further thought that the "duas petras, ex quibus ingens vis fluminis excidebat," would seem to indicate the *Karuma Falls*, where the two Roman officers terminated their exploration, but which the two English officers, Captains Speke and Grant, have now so successfully completed, and by gallantly following that branch to its entrance into the Mediterranean Sea, have proved it to be the *true* Nile.

On Anthropological Classification. *By* Dr. JAMES HUNT, *F.S.A.*

After the author had given a short outline of the nature of the subject, in which he stated that the origin of man belongs entirely to mythical times, and is a question which could not be solved by human experience, he proposed merely to classify man as he now exists, or as he has existed since the historical period, without reference to those distinctions being absolutely original. The scope of the present paper was to inquire whether these physical differences were so well marked as to serve as the basis of classification. He reviewed the classifications of Ephorus of Cuma, Buffon, Linnæus, Gmelin, Herder, Voltaire, Blumenbach, Lacépède, Duméril, Maltebrun, Cuvier, Virey, Hunter, Lawrence, Metzan, Bory, Desmoulins, Prichard, Lesson, Fischer, Morton, Latham, Hombron, Jacquinot, D'Omalius d'Halloy, Pickering, Burke, Knox, Agassiz, Crawfurd, and Isidore Geoffroy St.-Hilaire, and offered critical remarks on each system. The multiplicity of the systems at present in vogue is a sufficient refutation of the truth of most of them. The author considered that anatomy and physiology were the primary sources whence an adequate knowledge of the principles of anthropological classification could be derived. Language is no test of race. He laid great stress upon the form of the cranium as the most convenient and certain distinctive mark, and spoke with great approval of the ternary classification adopted by Gratiolet, who divides mankind into the frontal (European), parietal (Mongol), and occipital (Negro) races—these cranial distinctions being coincident with the mental and moral characters which were solely dependent on man's physical structure. Other secondary physical characters could also be used with advantage; and the author especially alluded to the classifications which might be based upon colour, stature, hair and beard, longevity, diseases, temperaments, odour, entozoa, and other subsidiary points of distinction. The degree of intelligence was the chief character distinguishing man from the inferior animals. If a classifier of the negroes of the West Indies were to use language alone as a criterion, he would classify them under the head of Europeans, with whom their acquired language is identical; their physical characters alone mark them as African. The author considered that language must be utterly discarded as the first principle of anthropological classification. He gave a far higher value to religion and to art, considering language merely as the third element. That there are well-marked physical, mental, and moral distinctions in

mankind is as well-ascertained a fact as that there are differences in the orang and the chimpanzee. We must, therefore, classify mankind according to the physical and psychological differences which now exist; for the present state of anthropology will not enable us to say how and when these distinctions have originated.

On the Physical and Mental Characters of the Negro.
By Dr. James Hunt, *F.S.A.*

The object of the paper was to determine the position which one well-defined race occupies in the genus *Homo*, and the relation or analogy which the negro race bears to animated nature generally. The skin and hair are by no means the only things which distinguish the negro from the European, even physically; and the difference is greater still mentally and morally. The skeleton of the negro is generally heavier, and the bones are larger and thicker, in proportion to the muscles, than those of the European. The thorax is compressed; the leg is longer than in Europeans, but is made to look shorter on account of the ankle being only between $1\frac{1}{3}$ in. to $1\frac{1}{2}$ in. above the ground; the heel is both flat and long. Burmeister has pointed out the resemblance of the foot and the position of the toes of the negro to that of the ape; and many observers have noticed that some negroes frequently used the great toe as a thumb. The hair is essentially different; and the voice resembles sometimes the alto of a eunuch—there being a peculiarity about it by which it can always be distinguished. The assertion that the negro only requires an opportunity for becoming civilized was stated to be disproved by history. The African race have had the benefit of the Egyptian, Carthaginian, and Roman civilization, but nowhere did they become civilized. The many cases of civilized blacks are not pure negroes; but, in nearly every case where they had become men of mark, they had European blood in their veins. In the West Indian Islands it has frequently been observed that all the negroes in places of trust which require intelligence have European features. Negro children are precocious; but no advance in education can be made after they arrive at the age of puberty; they still continue mentally children. After citing authorities to prove the low psychological character of the negro, the paper continued:—"We now know it to be a patent fact that there are races existing which have no history, and that the negro is one of these races. From the most remote antiquity, the negro race seem to have been what they now are." The author could see no evidence to support the opinion of some writers that the negro had degenerated from some higher form of civilization. The general deductions he would make were—first, that there is as good reason for classifying the negro as a distinct species from the European as there is for making the ass a distinct species from the zebra; secondly, that the negro is inferior intellectually to the European; thirdly, that the analogies are far more numerous between the negro and the ape than between the European and the ape. There was in the negro that assemblage of evidence which would induce an unbiassed observer to make the European and negro two distinct species.

Some Facts respecting the Great Lakes of North America. By J. A. Lapham.

On the Extinction of Races. By R. Lee.

The author gave statistics showing the rate of extinction of the various tribes which have given way to modern civilization. He stated that it might be suggested as an almost abstract question for discussion whether the disappearance of the aboriginal tribes might be taken as a type of what might happen at a future period of the world's history, when the present population shall have given place to an order of beings superior to the now dominant race of mankind. Europe was now the centre from which this flood of civilized life was overspreading the globe, and our own Anglo-Saxon race contributed one of the chief elements of that civilization. It might be the lot of nations now springing into existence at the antipodes to outstrip her in the pursuit of knowledge, and, when ages shall have passed away, to supply a nobler race and a more perfect humanity to the lands which now rank foremost in civilization. Viewed as a bare fact, and taking it in con-

nexion with what we knew of the previous history of man, there was nothing in the extinction of races to justify us in regarding it as a type of anything to follow at some future period. The man who now wanders free through the unknown wilds of Australia had not only not advanced in moral development since the formation of his species, but he had actually retrograded. We must, therefore, regard this extinction of races rather as an illustration of humanity in its crudest form shrinking and passing away before a race endowed with superior intelligence.

On the recent Discovery of Lacustrine Human Habitations in Wigtonshire. *By* Lord Lovaine.

Dowalton Loch, in which the structures about to be described were discovered, is a sheet of water of very irregular form, about two miles long and half a mile broad, situated in Wigtonshire, on the west coast of Scotland, at the end of a narrow valley five miles in extent, the whole of which is occupied by a moss, part of whose waters flow into the loch, and the remainder into the sea near Monreith; the elevation of the watershed near the middle of the valley being almost imperceptible. Sir William Maxwell, of Monreith, has effected the drainage of this loch at his own heavy expense, to the great benefit of his neighbours as well as himself, by a cutting at its southern extremity of no less than 25 feet deep, for a considerable distance through the wall of whinstone and slate that closes the valley. The water having been partially drawn off, the bed of the loch exhibits the appearance of an immense sheet of mud, surrounded by beaches of different elevations, covered with large rolled stones and angular blocks of slate. It contains a few small islets, composed, apparently, of the same materials as the beaches. Sir W. Maxwell, having heard that a bronze vessel had been found in the mud near the southern shore, succeeded in obtaining it, but could not trace other articles of the same description reported to have been found near it. On visiting the spot, 19th of August, 1863, to obtain further information, I observed some timbers standing on an island near the centre of the loch, and was told that some one had been there in a boat when it first appeared above water, and had found bones, a small granite quern, and piles; and a spot was pointed out to me at the extremity of one of the little promontories, where similar piles were observable, which, on inspection, I found to be true. These piles varied from a foot to eighteen inches in circumference. Sir W. Maxwell's bailiff, Mr. Chalmers, who displayed great zeal and intelligence throughout these researches, having proceeded to the spot to secure labourers for the next day's search, reported that, though it was not possible to reach the larger island, a smaller one was accessible, and that a canoe lay near it. On reaching the island, over about 40 yards of mud, I found it nearly circular, about 38 yards in circumference and 13 in diameter. It was elevated about 5½ feet above the mud, and on each side of it were two patches of stone, nearly touching it. On the north side of it lay a canoe of oak, between the two patches, and surrounded by piles, the heads just appearing above the surface of the mud; it was 24 feet long, 4 feet 2 inches broad in the middle, and 7 inches deep, the thickness of the bottom being 2 inches. On removing the stones which covered the surface, several teeth, apparently of swine and oxen, were found; and I proceeded to cut a trench round the islet; and upon coming to the southern end, a small quantity of ashes were turned up, in which were teeth and burnt bones, a piece of a fine earthenware armlet of a yellow colour, and a large broken earthenware bead, striped blue and white, together with a small metal ornament, apparently gilt; two other pieces of an armlet of the same material, one striped with blue and white, were also found on the surface. On cutting deeper into the structure (the foregoing objects having been found on the outside about 2 feet from the top), it proved to be wholly artificial, resting on the soft bottom of the loch; the uppermost layer was a mass of brushwood about 2 feet thick; beneath it large branches and stems of small trees, mostly hazel and birch, mingled with large stones, evidently added to compress the mass; below that were layers of heather and brushwood, intermingled with stones and soil, the whole resting upon a bed of fern about 1 foot thick, which appeared in all the structures examined to form the foundation. The whole mass was pinned together by piles

and stakes of oak and willow, some of them driven $2\frac{1}{2}$ feet into the bottom of the loch, similar to those above mentioned. The islet was surrounded by an immense number of these, extending to a distance of 20 yards around it; and the masses of stone, which apparently were meant to act as breakwaters, were laid amongst them. The one next examined stood about 60 yards off, at the extremity of a rocky projection into the loch, but separated from it by the now hardened mud. It was smaller, and the layers were not so distinctly marked, and some of the timbers inserted in it under the first layer of brushwood were larger, and either split or cut to a face. A stake with two holes bored in it about the size of a finger, a thin piece of wood in which mortises had been cut, and a sort of box, the interior of which was about 6 inches cube, with a ledge to receive the cover, very rudely cut out of a block of wood, were found. I succeeded two days afterwards in reaching the largest islet in a boat. It appeared by measurement to be 3 feet below the level of the other islets; but it was much larger, and several depressions on its surface showed that it had sunk. Wherever the soil was not covered with stones and silt, teeth were scattered all over it. We found quantities of bones at different depths in the mass, but always below the upper layer of faggots, and towards the outside. The progress of the excavation was very soon stopped by the oozing in of the water; but a workman, plunging his arm up to the shoulder into the soft material, brought up handfuls of the fern layer, mingled with sticks and hazel-nuts and large bones, believed to be those of oxen. Near the spot lumps of sand and stone, fused together, were picked up. On the south side of the island extraordinary pains had been taken to secure the structure: heavy slabs of oak, 5 feet long, 2 feet wide, and 2 inches thick, were laid one upon another in a sloping direction, bolted together by stakes inserted in mortises 8 inches by 10 inches in size, and connected by squared pieces of timber 3 feet 8 inches in length. It extended to the length of 23 yards, and its base, about 5 yards beyond the surface of the mud, was formed of stems of trees laid horizontally, and secured by stakes. In other respects the formation resembled that of the other islet, but it was far larger, measuring 100 yards round by about 36 yards across. No building of any sort was discovered; but a large plank of oak, 12 feet long, 14 inches broad, and 7 inches thick, lay covered with stones on the north side. The sinking of the mud had by this time laid bare a second canoe between the islet first examined and the shore; it was $18\frac{1}{2}$ feet long, 2 feet 7 inches wide, and barely 2 inches deep; a block of wood, cut to fit a hole left probably by a rotten branch, was inserted in the side, 2 feet long, 7 inches wide, and $5\frac{1}{2}$ inches thick, and had there been secured by pegs driven through the side; across the stern was cut a deep groove to admit a backboard; a hole 2 inches in diameter was bored at about one-third of the length of both canoes in the bottom. This was so rotten that it would not bear my weight without breaking. The next day, being unable to reach the last-mentioned island, I found upon the spot which had been indicated to me on my first inquiry, no less than six structures similar to those before described, in a semicircle. They were, however, much smaller, apparently single dwellings. Though upon some of them charred wood was found, nothing else was discovered except a mortised piece of timber, which might have drifted there; and in one, inserted under the upper layer of brushwood, a large oak timber, measuring 8 feet long by 3 feet in circumference. Throughout these investigations, no tool or weapon of any sort has come to light. In the layers the leaves and nuts were perfectly fresh and distinct, and the bark was as plainly distinguishable on the stems and timber as on the day they were laid down, as were also the heather and the fern. It is difficult to conjecture the state of the loch when these edifices were formed, and whether or not they were completed at one period. The finding of the large stones in the lower layer of ferns might lead to the belief that they were gradually raised as the waters of the loch increased; and the necessity of strengthening them by breakwaters would seem to prove that the loch must have risen considerably before they were abandoned. No other sort of building has been discovered on them; but the great number of teeth scattered over the surface of the larger island, and even on the mud surrounding, and the immense expenditure of labour indicated in the shaping and hewing of the large timber with tools, which must have been, from the work produced, of the rudest description, betoken apparently a considerable population. The loch must have

remained for a considerable period at each of the different levels before mentioned; at one time 6 or 7 feet above its last level (that is, before its drainage was effected), to which it was reduced by three cuts made to feed neighbouring mills, one certainly of great antiquity. At $3\frac{1}{2}$ feet below the ordinary level there are unmistakeable appearances of a former beach, with which the top of the first-mentioned islet almost exactly coincides. It is remarkable that though there are many rocky eminences in the bed of the loch, none bear token of ever having been used for the erection of these dwellings, which seem invariably to have been based upon the soft bottom of the loch, where the intervening mud and water may have afforded the inhabitants a greater security from attacks from the shore. I had not time to examine fully the shores of the loch; but I was assured by Mr. Chalmers that he had examined them carefully without finding traces of other structures. On a hill to the south there are remains of a Danish fort * (*i. e.* a circular entrenchment), and the very ancient ruin called Long Castle is on an adjacent promontory on the north side. Since writing the above, a very old man in Sir William Maxwell's service told me that in clearing out a channel between a small wooded island in Myston Loch, close to Monreith House and the beach, he remembers there being found layers of timbers, piles, and flat stones laid in circles. I have also obtained from a farmer living near Ravenstone Moss a paddle of black oak, 3 feet long, 14 inches broad, and 1 inch thick, which, with four or five others, he had found in that moss, lying close to a mass of timbers about 6 feet from the surface; this, I have every reason to believe, formed part of a structure similar to those described. I should have mentioned that, though retaining its shape, the timber is for the most part completely decayed, except where it has been protected from the action of the mud. Dowalton Loch lies one mile to the left of the high road, halfway between Wigton and Port William. The name of the loch is probably derived from the Macdowals, formerly lords of this part of the country, and possibly of Irish origin, constant communications with the north of Ireland having taken place from the earliest period. Sir William Maxwell suggests as an easy explanation of the different levels found in the loch, that the waters originally discharged themselves into the sea from the western end of the valley, a portion of them only now finding an exit that way, in consequence of the formation of the moss towards the centre of the valley, which compelled the remainder to flow into the loch. In this case the structures must be supposed to have been formed in the early stages of the growth of the moss, whilst the loch was so shallow as to make it easy to raise the moss above its waters, and yet deep enough to float canoes, and afford the desired security from an enemy.

On Two Ascents of the Volcano of Misti. By the Hon. R. Marsham.

On his Travels towards the Sources of the Nile. By Signor Miani.

M. Miani indicated some trifling matters in which he asserted that the geography of the explorers was at fault, and concluded by expressing a hope that the Emperor of Austria would grant him money to make another expedition to ascertain whether he or they were wrong.

On the Tribes, Trade, and Resources around the Shore-line of the Persian Gulf. By Colonel Pelly.

On the Antiquities of the Orkneys. By G. Petrie.

Proposed Interoceanic and International Transit Route through Central America. By Captain Bedford Pim, *R.N.*

It is with peculiar pleasure that I introduce my present subject to your notice, because I firmly believe that the result of the labours of myself and my com-

* This has subsequently proved, on closer investigation, to be decidedly Roman. A Roman fibula in bronze has also been picked up on the larger islet.

panions during the explorations in Central America, from which we have just returned, will not alone prove interesting as additions to our geographical knowledge, but be the means of conferring happiness upon hundreds of thousands of our fellow-countrymen at the antipodes, of vastly increasing and directing the flow of commerce from the great producing countries of the Pacific into English channels, and, furthermore, of offering to our energy and capital a new field of enterprise of boundless extent and inexhaustible resources.

I propose to discuss my subject under two heads, viz.:—1. The physical aspect of Central America; 2. The great political and commercial importance of a railroad transit across it.

In defining the boundaries of Central America, I do not restrict myself to that part commonly called the Isthmus of Panama, but include the entire country, from the first narrowing of North America at Tehuantepec to its final expansion into South America at Darien. This large extent of country, the centre of the New World, is included between the 7th and 18th parallels of north latitude and the 77th and 94th meridians of west longitude. There are no less than four crossings or isthmuses within the above boundaries, the narrowest of which, in lat. 9° north and long. 79° west, is only 27 miles across, while the broadest is not 200 miles from ocean to ocean. The extent of the coast-line, counting all its sinuosities, is 3000 miles, the length from end to end about 1350 in a direction N.W. and S.E., and the area 306,000 square miles, or about the size of England and France. The population is about 2,859,000, or an average of rather more than nine to the square mile.

The climate of Central America is equable. There are two seasons, the wet and dry, or summer and winter.

The maximum range of the thermometer in the interior of Nicaragua, the central state or republic, is about 90°; the temperature in the dry season is much cooler, and often quite chilly; but the following observations will give some idea of the atmospherical laws by which the climate is governed. Annual rain-fall 97·7 inches; rain fell 138 days; mean highest temp., 86°; lowest, 71°; yearly average, 77°.

The prevailing type of disease is a low intermittent fever; but that the general healthiness of the country is above the average in the tropics is proved by the vigorous old age of the inhabitants and the small percentage of deaths amongst the residents. The more violent forms of disease have never been experienced, and yellow fever is unknown.

The general aspect and scenery of Central America is most varied, and perhaps, on the whole, unrivalled in the world. The Atlantic coast-line is for the most part low, and fringed with primeval forests; magnificent rivers, coming from the far interior, empty themselves into the Caribbean Sea, and these again are intersected near their mouths by extensive lagoons, forming an interior navigation, close to the shore, for many hundreds of miles, and offering the greatest facilities for the growth and export of cotton of any locality I have ever visited.

Inland, nature has been prodigal of her gifts, and has put on her grandest forms. Towering mountains and volcanos, magnificent savannas, level plains, and beautiful lakes, dotted with the most romantic islands, the whole combined with a fertility of soil and salubrity of climate unsurpassed in the tropics.

Of its manifold productions those best known are precious metals, cochineal, indigo, sarsaparilla, vanilla, india rubber, balsam, copal, cotton, copaiba, cocoa, coffee, tobacco, hides, mahogany, cedar, live oak, several dyewoods, pitch-pine, containing a large quantity of tar, lignum vitæ, cascarilla, a great variety of hard woods, silk-grass, tortoise shell, &c.

In short, from its geographical position, climate, and inexhaustible natural wealth, Central America may safely be looked upon as offering to enterprise the most desirable field in the world.

The above is a brief sketch of the centre of the New World under its physical aspect. It remains to point out in what manner so promising a country may be utilized. I propose, by the construction of a transit by railroad from the Atlantic to the Pacific Ocean, through the heart of the central state, or rather republic, of Nicaragua, to open up the entire country; and I am anxious to make this transit a great highway of nations for all the world.

The political necessity of such a route is proved beyond cavil or dispute by the following words of the Duke of Newcastle, Colonial Secretary, spoken from his place in the House of Lords, session 1862:—"A short time back, when there was an apprehension of hostilities with the United States (the Trent affair), he was unable to communicate with the Governor of British Columbia for the space of six weeks, there being the possible chance of any dispatches sent *viâ* Panama falling into hostile hands."

At present the only means of crossing from the Atlantic to the Pacific is by the Panama Railroad, which is essentially an American undertaking, and exclusively devoted to the interests of the United States.

The speech above points out the sort of political paralysis our statesmen are liable to while this state of affairs continues, and it is unfortunately only too easy to prove that our merchants trading with that part of the world are liable at any moment to a similar commercial paralysis, which it might not be so easy to recover from; indeed the blow might have been dealt long before this, had not the fearful war and dismemberment of the United States fully occupied the attention of its citizens.

With regard to the Great Transit Route I have proposed, it is right that I should just sketch its rise and progress.

In 1859–60 I was stationed on the coast of Central America (Atlantic side), as senior naval officer in command of H. M. S. 'Gorgon,' and then first conceived the idea of a transit through Nicaragua. The nature of the service I was at that time employed upon precluded the possibility of any elaborate survey or explorations; but all my investigations went to prove the practicability of my project, and subsequently, after paying off the 'Gorgon,' I was enabled to go thoroughly into the matter. I have now just returned from Nicaragua, and am happy to say that my surveys and sections prove beyond doubt the practicability of a railroad from ocean to ocean, with good harbours at each terminus, and facilities in other respects for opening a great highway of nations such as I believe no other interoceanic project has yet offered.

The route starts from a headland on the Atlantic, called Monkey Point, thirty miles north of Greytown, runs in a westerly direction to San Miguelito on the Lake Nicaragua, skirts the northern side of that lake, crosses the River Tipitapa, and following the south side of Lake Managua, passes through the city of Leon, and finally terminates at Realejo on the Pacific.

The construction of such a railroad across Nicaragua would open up the finest cotton country in the world, formed by nature for the cultivation of the plant, and enjoying a geographical position in close proximity to the best market. The railroad transit, while it would make England independent of the American monopoly at Panama, would shorten the route to British Columbia by several days, open up the Japanese trade, and bring us within forty-five days of Australia and forty-one of New Zealand, thereby knitting those colonies, and securing their commerce to the mother country more firmly than ever.

We have every encouragement to proceed. See what the Suez line has done for India; it has brought that country much closer to England, and afforded the best guarantee for its future prosperity and permanent connexion. For instance, in 1861, 759 miles of railroad were made, and 747 in 1862,—that, too, in a country where it was previously demonstrated to be an impossibility to construct railroads, owing to the monsoons, the crumbly soil, the rapid vegetation, the white ant, the heat, the poverty of the inhabitants, the want of labour, the idleness of the poor, and the lassitude of the rich.

Eastern Australia, New Zealand, and our North Pacific colonies are now calling loudly upon us to treat them at least as well as our adopted Indian children. We are bound by every law to do so. The opportunity of knitting these colonies to us, and making them as profitable as India, is doubtless offered, by opening a speedy means of transit between them and us. Suez is an example; let us read the lesson right, and no longer persist, by a suicidal apathy, in estranging from us such loyal fellow-subjects and good customers.

On the Marganza. By the Rev. J. L. Proctor.

On the Opening of a Cist of the Stone Age near the Coast of the Moray Firth. By E. Roberts *and* Prof. Busk, *F.R.S.*

Mr. Roberts said that, in company with his friends Dr. Gordon and Mr. Harvey Gem, he had lately visited two mounds situated upon the sandy shores at Bannat Hill, a mile from Burghead; and after examining their contents, they turned their attention to the small cairns of rudely piled stones which lie a few yards from one of the shell-middens, and which evidently marked the burial-places of the tribe. Two of these were piled around small enclosed spaces, formed by the junction of four upright stones. A fragment of human jaw lying on the sand outside one of those led them to search among its contents for other bones, but unsuccessfully. The second cairn, however, with its central cist, yielded better evidence. This, like the neighbouring tomb, was a rude erection of four flat sandstone-slabs, placed vertically, so as to enclose a space 30 inches long by 20 inches in width. The depth of the stone, which nearly corresponded with that of the grave, was 22 inches. Three of the stones had been slightly smoothed before being used. The direction of this grave was S.S.E. by N.N.W. This, however, was of no moment, as the adjoining one differed so much in this respect as to lie at nearly right angles to it. The cavity thus formed was filled with sand, into which they dug, and presently succeeded in discovering a skeleton, which had apparently been buried in a crouching position, the legs below the knee being bent beneath the hams, and the head bowed towards the knees, and presenting peculiarities which Mr. Busk had described in a note attached to the paper. From the position of the skeleton Mr. Roberts was at first inclined to consider that the cist had never been broken into, but the absence of some few of the vertebræ and of the smaller bones rendered this somewhat uncertain, though the disturbance, whether from curiosity or another motive, seemed to have been insignificant. He regretted, however, to add, that the box in which he packed the bones was tampered with during its transit from Elgin to London, and some of the bones, including the lower jaw, from which precious evidence might have been obtained bearing on the Moulin-Quignon enigma, never reached him. No pottery nor fashioned stones accompanied the skeleton. The note by Professor Busk was to the effect that the bones had belonged apparently to a young individual, about 5 feet 8 or 9 inches in height, of slight make, and no great muscular development. At first sight, from the comparative delicacy of form and want of muscular impressions, one would be inclined to regard them as those of a woman, but, if so, she must have been of more than the usual stature. Unfortunately, no part of the pelvis, which would enable a correct judgment as to this point to be formed, was found among the remains. If they were a man's, he must have been of small size, and not of a strong build, with a remarkably small head for a male. The cranium was decidedly *brachycephalic*, the proportion of length to breadth being as 1·00 to ·823, and for its size rather unusually high, the proportion of that dimension being to the length as ·808 to 1·00. The forehead was narrow, and the supraorbital ridges very slightly projecting, although the frontal sinuses were well developed. Compared with other ancient crania, this might be regarded as belonging to the same class as those which had been considered as appertaining to the stone-period of the North of Europe.

On the Physical Geography of Guatemala. By O. Salvin.

On Ethnographical Casts. By Hermann Schlagintweit.

On the Ethnology of Ceylon, referring especially to its Singalese and Tamil Inhabitants. By Mutu Coomara Swamy.

The author commenced by saying that the population of Ceylon was nearly three millions, and that its inhabitants, who were distributed among a great variety of races, might be classified under the heads of European, Asiatic, and Eurasian. The European population was not great, and consisted chiefly of English, Irish,

and Scotch emigrants, employed in the civil and military service or on the plantations. The Asiatics of Ceylon are the Veddahs, the Singalese, the Tamils, the Moors, and the Malays. The Veddahs are hunters, and are supposed to be the aborigines of the island. The Tamils of Ceylon belong to the same race as the Tamils of Southern India, and consist either of those who have been on the island for centuries or who are recent emigrants. They are to be chiefly found in the north-east portion of the island, and their two great capitals are Jaffna and Trincomala. Their main occupation is agricultural. The coolies are the labourers of the island. They cross over in large numbers from the continent during the coffee-season. The Singalese are the inhabitants proper of Ceylon, and range themselves under the heads of Kandians, low-country Singalese, and Rhodiahs. The Kandians are the inhabitants of the hill-country, and are a hardy robust race, never till recently intermingling with their low-country brethren. Their language is made up of three component parts—Elu (a Singalese pure), the Pali, and the Sanskrit. They possess an extensive literature, and their religion is Bhuddism. The low-country Singalese are either Buddhists, Roman Catholics, or Protestants. The influence of Roman Catholicism is very great, and the people are divided into classes after their occupations. The Malay population of the island is small, and the inhabitants form the Ceylon Rifle Regiment. They are faithful soldiers, brave and obedient; and in their religion thorough Mahommedans. The Moors are the small traders and shopkeepers of the island.

On the Anatomical Characters of the Skull found by Mr. Duckworth. *By* William Turner, *M.B., F.R.S.E.*

A description of the form and general characters of this cranium was given, one of the most interesting features connected with it being its resemblance to the much-discussed "Engis" skull, of which it might almost be considered to be a reduced copy.

On the Varieties of Men in the Malay Archipelago. By Alfred R. Wallace, *F.R.G.S.*

In the Malay Archipelago are found two very strongly contrasted races—the Malays and the Papuans. The former inhabit the great western islands, Sumatra, Java, Borneo, and Celebes; the latter New Guinea and the adjacent small islands. The typical Malays are of a light brown colour, resembling cinnamon or lightly roasted coffee; they have constantly straight black and rather coarse hair, little or no beard, and generally smooth hairless bodies; they are of a low stature, rather strongly made, with short thick feet and small delicate hands. The face is broad, the eyebrows flat, the nose small, well-formed, with the nostrils somewhat exposed; the lips broad and well cut, the mouth large but not projecting. In character the Malay is impassive, reserved, and bashful. His feelings of surprise, admiration, or fear are not readily manifested, and he has little appreciation of the sublime or beautiful. He is somewhat taciturn, is deliberate when he speaks; he but seldom laughs, nor does he openly express his gratitude for a favour. He revenges an insult more quickly than an injury. He is honest and trustworthy in many matters, but prides himself upon his capacity for lying. His intellect is but mediocre; he is deficient in the energy necessary to acquire knowledge, and his mind seems incapable of following out any more than the simplest combinations of ideas. He is quick in acquiring mechanical arts, and therefore makes a good servant for simple routine duties.

The Papuan is, in many respects, the opposite of the Malay. In colour he is a deep sooty brown or black; his hair is very peculiar, being harsh, dry, and frizzly, growing in little tufts, which in youth are short and compact, but which in adults often grow out so as to form a compact frizzly mop, nearly a yard in diameter. He is bearded, and his arms, legs, and breast are more or less hairy. The Papuan is taller than the Malay, and, perhaps, equal to the average of Europeans; the face is elongate, and the hands and feet rather large; the forehead is flat, the brows very prominent; the nose large, long, and arched, with the nostrils hidden by the overhanging tip. The face has thus a Semitic character, which is perceptible even in

the children. The moral characteristics of the Papuan separate him widely from the Malay. He is impulsive and demonstrative in speech and action. His emotions and passions are expressed in shouts and laughter, in yells and frantic leapings. He is noisy and boisterous in speech and action, both at home and before strangers. Of his intellect less is known, but it seems at least equal and probably superior to that of the Malay. He has a love of art, decorating his canoe, his house, and almost every domestic article with elaborate carving. It must be granted, therefore, that these two races are most strongly contrasted; and if mankind can be classed at all in distinct varieties, the Malay and the Papuan must certainly be kept separate. Besides these well-marked races are the inhabitants of the intermediate islands of the Moluccas and Timor, which, though differing in some degree from both, may yet, in almost every case, be classed with one or the other of them. The Negritos of the Philippines, and the Semangs of Malacca, differ in most important characters from the Papuan races, with which they have hitherto been classed, and must be considered to have Asiatic rather than Polynesian affinities. The recent evidence of the antiquity of man, and his having survived geological changes and the extinction of many species of Mammalia, introduces a new element into ethnographical researches, and enables us to speculate more freely on the derivation and origin of races. Mr. Darwin's researches on the structure and origin of the coral-reefs of the Pacific render it highly probable that great islands, or even continents, have recently sunk beneath its waters. The present distribution of animals in the Pacific islands leads us to conclude that this subsidence is geologically recent. The inhabitants of all the Pacific islands, as far west as New Guinea and Australia, have much in common, while they differ greatly from other races. Combining these facts, and boldly following their indications, we may divide the Malay Archipelago by a vertical waving line through the Moluccas, so that all the tribes to the west of the line will be Malayan or of Asiatic origin, and all to the east Papuan or of Polynesian origin. This division is in harmony with that which has been shown to exist in the animal productions of the same regions, and obviates the difficulties attending every theory hitherto proposed as to the affinities and derivation of the Malayan and Polynesian races.

On the Central Argentine Railway from Rosario to Cordova, and across the Cordillera of the Andes. By W. WHEELWRIGHT.

This railway commences at the city of Rosario, in the province of Santa Fé, on the right bank of the La Plata, in latitude 32° 56′ south, longitude 61° 30′ west, and about 250 miles above Buenos Ayres by the channel route, which is navigable for ships of a large size, and has a depth of 16 feet of water; it possesses a very fine harbour and all the elements of prosperity, and is the great commercial *entrepôt* of the interior provinces. Here the steamers which ply between Montevideo, Buenos Ayres, and Paraguay, and those engaged in commerce with Corrientes and other commercial points stop, while almost a daily intercourse by steamers is kept up between this port and Buenos Ayres. From Rosario the railway will pursue its course in a north-west direction over those vast and fertile plains to Cordova, the central city of the plains, 247 miles, and thus will form the great trunk line, having upon its south and west the provinces of Mendoza, San Juan, San Luis, and the interior of the province of Buenos Ayres, whose high roads all concentrate upon the line of railway about midway; on the north are the provinces of Tucuman, Santiago del Estero, Jujury, Catamarca, and Rioja, with all their roads concentrating at Cordova, and thus forming one of the most extraordinary combinations to be found in the annals of railways. The railway is a work of great magnitude, and is intended to go over mountains at an elevation of 16,023 feet.

Notice of the Discovery of Three additional Runic Inscriptions in St. Molio's Cave, Holy Island, Argyleshire. By Prof. D. WILSON.

On the Rivers of the Interior of Australia. By the Rev. J. E. WOOD.

ECONOMIC SCIENCE AND STATISTICS.

Address by William Tite, *M.P., F.R.S., President of the Section.*

The general business of this Section will be preceded by a few opening remarks which I shall have the honour of addressing to you, and we will then proceed with the papers on the programme for the day. One of the usual duties of Presidents seems to be the presentation of an opening Address; but in accepting the office I have now the honour of filling, it appeared to me that our time would be better occupied in considering the papers we may have submitted to us than in occupying a considerable portion of your time by opinions of my own upon the subject. I was the more led to this because on looking at what has been done by the gentlemen who immediately preceded me, viz. Mr. Newmarch, in 1861, at Manchester, and Mr. Chadwick last year at Cambridge, it appeared to me that each of them had almost wholly exhausted the subject, with regard to the objects and topics of statistics and economical science, and the admirable *résumé* of Mr. Newmarch in 1861 showed what has been done so correctly and completely during the thirty years over which his experience extended, that it left little for me to say. One or two subjects obviously and naturally suggested themselves, and in referring to Mr. Newmarch's address, we find an admirable calculation of the results, with which statistical inquiry is more immediately concerned. He says, "These seem to me six-fold, viz., first, all such problems as relate to the real nature of wealth, and to the production and growth of wealth in a community; second, all such as relate to the exchange of commodities, that is to say, to inland and foreign trade; third, all problems relating to taxation and finance; fourth, problems relating to currency, banks, and prices; fifth, problems relating to the wages and the hire of labour, and the division of employments; and lastly, problems relating to the functions of the State as regards interference with the economic relations of its subjects." These are all so clearly expressed and put, that I cannot do better than present them to your notice, and call attention to this able statement of our objects and duties. He continues thus: "With respect to the first *three* of these groups of problems, it is probable that no further important doctrines remain to be discovered. There is little further to be found out concerning the real nature of wealth, concerning the true principles of exchange, or concerning taxation and finance, beyond the conclusions already established and expounded." I should, however, be glad if the present position of monetary affairs in America could be brought forward and fully discussed in this Section; for her statesmen and merchants appear to bid defiance to all the laws and calculations of statistics. I should therefore very much like the exact condition of the currency system in America, and information as to the extraordinary amount of debt they have certainly created, to be brought under your consideration. One other topic I must mention, which is best explained in the following words in the Report of the Parliamentary Committee:—"A Committee of the House of Commons having reported in favour of the adoption of the Metrical System of Weights and Measures, and it being understood that a Bill to carry into effect such recommendation will be introduced in the ensuing Session of Parliament, your Committee venture to suggest that the expediency of such a measure might be discussed at the ensuing Meeting." My friend, Colonel Sykes, supplemented this report with a statement that a Bill relative to this had been introduced subsequently to the report of the Committee being prepared, and that it had been read a first and second time, the latter occupying the House nearly the whole of one day; and, notwithstanding the opposition of Government, the measure passed the second reading. I think the most convenient course would be not to enter at present again on a fresh discussion of this subject, because the principle of the measure has been thus affirmed by Parliament, and it has also been very fully discussed in the Meetings of the Social Science Association. After remarking on the beneficial effects of the newly established Social Science Association, and the cordiality existing between it and the British Association, the chairman concluded.

The Volunteer Force; its Comparative Cost, Development, present State and Prospects. *By* Lieut.-Colonel HENRY C. ALLHUSEN.

Scarcely four years have elapsed since certain political causes induced the people of this country to arm in its defence, and to originate that movement which so soon resulted in the organization and establishment of the present volunteer army. The first steps were taken under Lord Derby's administration by General Peel, the Secretary of State for War, who accepted the services of several corps in the spring of 1859, and afforded them every facility within his power. When the present Government came into office thirteen corps were established, and although at that time every expense had to be borne by volunteers, the force increased with extraordinary rapidity, its enrolled strength rising to 150,000 men in June 1861, and attaining the maximum (163,000) in April 1862. It was, however, shortly found that the pecuniary sacrifice entailed by this voluntary enlistment was so great as to necessitate assistance on the part of the State, and the first contribution was granted by Lord Herbert, who supplied 25 per cent. of the arms and ammunition; but uniformity in equipment being subsequently deemed essential, it was determined to issue the full quantity. This was followed by the appointment of adjutants and drill instructors, and lastly by the adoption of the capitation grant, recommended last year by the Royal Commission. In consideration of this support, and to ensure its proper application, the Act of George III. has been repealed by the Volunteer Act introduced this Session by the Marquis of Hartington, the Under Secretary of State for War. It possesses the advantage of placing a limit to inefficiency by clearly defining the terms on which a volunteer is to be considered effective; and with reference to the provisions regarding discipline, the voluntary nature of the service virtually annuls the power any of these clauses might seem to confer on commanding officers. In this force control must mainly depend on example, and can be exercised with good effect only when supported by reciprocal esteem and confidence; in fact, a successful combination of discipline and efficiency cannot be attained unless moderation, good feeling, and a proper spirit of emulation animate all the members in the discharge of their respective duties. Although undoubtedly much has been done to consolidate this great institution through the countenance of public opinion, the support of Her Majesty's Government, and the well-known favour and consideration with which the present Secretary of State, Lord de Grey, has invariably regarded the volunteer force, yet it is probable that further measures will be found indispensable to ensure the permanence of its basis. The number of drill instructors is inadequate, and their qualifications below the requisite standard; the capitation grant should be raised to 40*s.* for garrison artillery, engineers, and rifles, and to 50*s.* for light horse and inland artillery corps possessing guns on travelling carriages; and, finally, a force of field artillery should be organized by issuing light field guns to such of the inland corps as may make application for them. The adoption of these suggestions would have the effect of reducing the cost entailed by serving in the volunteer force, which 30*s.* per man cannot entirely cover; would rescue inland artillery corps from their present anomalous position, and would improve the mobility of the volunteer army, and the self-supporting power of its several branches.

The total enrolled strength is now 159,000 men of all ranks, of whom 1300 are cavalry, 23,000 artillery, 2500 engineers, and 132,200 rifle volunteers. After comparing the cost of the several branches of Her Majesty's land service and its strength with that of the continental armies, the author concluded as follows:—"The people of this country, from their natural industry and energy, pay almost undivided attention to the pursuits of the day that interest them most; hence a long-continued peace produces apathy, and almost a dislike for all military exercises. Thus it is that, after Marlborough, the renown of the British arms seems gradually to have receded, until the glorious campaigns of Wellington again raised them to admiration; and although after forty years' peace the battles in the Crimea were fought with the utmost bravery, and under severe privations, yet on the Continent the prestige of our arms most certainly suffered, because our military organization was considered far from what it ought to have been. This, however, produced reforms which have placed the army in the highest state of efficiency, and now that the militia is well organized, the yeomanry regularly trained,

and the volunteer force still in its strength, England has a military armament equal to any emergency. The desired position, then, having been attained, every effort should be made to preserve it, and success, through Providence, will be certain if the other services continue efficient, and the volunteer army be rendered permanent. The idea of invasion may have become latent, or merged in the memories of the past; still men well know that as the tide of time rolls on, the nations, as they rise and fall in its course, can neither command the sunshine of peace nor prevent the thunder-clouds of war."

On the Vital and Sanitary Statistics of our European Army in India, compared with those of the French Army under like conditions of Climate and Locality. By Dr. James Bird.

The author showed that the mortality of 69·0 per 1000, adopted in the lately published 'Sanitary Report for India,' obtained under the insalubrious conditions of locality and climate, had been greatly ameliorated of late years. For the last twenty-six years, or from 1829 to 1855, the death-rate, inclusive of a considerable period of war, the Cabul massacre, the Scinde and Gwalior campaigns, and the two Sikh wars, was only 44·4 per 1000. For 1817, during the Pindaree war, the mortality per 1000 was 69·0; the average for the next six years of peace being 75·0. In 1824, 1825, and 1826, during the first Burmese war and siege of Bhurtpoor, the mortality rose to 129, 157, and 158 per 1000 for these years respectively; and for the next six years of peace fell to an average of 56 per 1000; and for the next eleven years of war, 1839 to 1849 inclusive, the rate vibrated from 47 to 124 during the first Sikh war—being for the eleven years an average of 74 per 1000. In the last six years, 1850 to 1855 inclusive, the average mortality was 37·3 per 1000. By the latest return of the British army in India, exclusive of the late East India Company's troops, it appears that the deaths in India amounted to 35·3 per 1000; and deaths on the passage home caused a further loss of 35·3 per 1000; being altogether a decrease of the whole strength of 68·6 per 1000. It was shown that invaliding, even at home, causes a decrease of 32·3 per 1000, while the average death-rate, exclusive of the Horse Artillery, was 14·7; so that this cause of decrement in India is not greatly in excess. In comparing these rates of Indian mortality in the British army with those of French troops, in their tropical colonies of Martinique, Guadaloupe, Guiana, and Réunion, during ten years—1838–47 inclusive—the mortality was 69·5 per 1000—vibrating between 90·4 and 25·3. In Algeria, in an effective strength of 108,000 men, for ten years, from 1837 to 1846 inclusive, the death-rate was 78·8 per 1000; and during 1846 it was 68·8; while the other casualties of discharged, sent to France, killed in battle, deaths in French hospitals, pensioned, and invalided, amounted to 28·3, increasing the total decrements of French troops in Algeria to 97·1 per 1000. The author also showed, that whereas at home, for fifteen years previous to 1854, the average death-rate was 14·7, and that of invalids 32·1 per 1000, those rates respectively in 1860 had fallen to 7·32 and 21·30, evidently a gain to the effective force of 18·38 per 1000. In the hot climates of Jamaica, Ceylon, and Mauritius, where from January 1830 to March 1837 the death-rates respectively were 91·49 and 34·6, they had fallen in 1860 to 20·2, 19·6, and 23·8 per 1000, proving beyond doubt that, with the introduction into India of improved sanitary appliances, adapted to climate and localities, and with restraints on vice and intemperance, correspondingly decreasing rates of augmented health among our troops must follow as natural results. The author, in conclusion, referred to Miss Nightingale's evidence, recorded in the Topographical and Statistical Reports, printed in the Appendix to the Sanitary Commissioners' Report of 1863.

On the Coventry Freehold Land Society. By C. H. Bracebridge.

After describing the six estates of the Society and their appropriation to building purposes, the author stated that the mode adopted for obtaining these results had been by a contribution of one shilling and sixpence per week per share being paid to a common fund, and when that fund had sufficiently accumulated, and estates offered in localities suitable to the convenience of members, they had been

purchased in the order shown in a Table exhibited. The streets on the estates have been substantially made and well culverted, regard having been paid to the best and most approved sanitary arrangements. When an estate was purchased, the allotments were offered to the members in priority as they stood upon the books, it being optional with the members whether they had their allotments in that or a future purchase; by this means the members generally have been enabled to obtain their allotment in such locality that they most approved. Members previous to the ballot were allowed to withdraw the amount they had subscribed, and sums amounting in the whole to £2681 14*s*. 6*d*. have been so withdrawn. When a member received his allotment, he was at liberty either to pay the balance at once or to give a mortgage to the trustees as security. About two-thirds of the members have given mortgages, the whole of which, with the exception of ten, have now been paid for by the ordinary contributions of one shilling and sixpence per share per week. The ten mortgages remaining are for 25 shares, and the amount remaining unpaid is about £100. The legal expenses were in each case of conveyance, and mortgage 32*s*. 6*d*., exclusive of stamp, whether for one or six shares. In the above manner 1108 allotments on six estates have been made, and the future transactions of the Society reduced to £100. The principal cause which has brought the managers to a determination to wind up the affairs of the Society have arisen from the great depression in the principal trade of the town during the last few years.

On the Sanitary Condition of the Troops in India. By Dr. Camps.

He said that the object of the paper was to call attention to a few of the facts stated in the report recently laid before Parliament of the Commission appointed by Her Majesty in 1859 to inquire into the health of all ranks of the army in India. From the data collected in the paper, it appears that the mortality of men of the soldiers' age in the healthy parts of England and Wales is such that eight die annually to 1000 living. In India the mortality per thousand at the age of 20–25 is 56·4; at 25–30 it is 48·8; and at 40–45 it is 61·6. The excess of mortality in India is nearly the same at all the seven quinquennial periods of age from 20 to 55, except at the first and fifth, when the recruits join and leave their corps in greatest numbers. This points to the influence of the term of service, and seems to justify the inference that the fatal causes in operation produce nearly the same fatal results in India at all the ages from 20 to 55 among men exposed to the same influences. From actuarial tables prepared by Dr. Farr, it seems that the expectation of life at the age of 20 is 17·7 years in India, and 39·5 years in England; so, therefore, life is shortened by 21·8 years. On an average, in the stations of Bengal, 84 men in a battalion of 1000 were constantly in the hospital. Thus, out of 1000 men at a given station, 84 of their number are sick in the hospital, and 69 die annually. With this amount of sickness, an army of 70,000 British troops in India has, so to speak, a vast hospital of 5880 beds constantly full of sick, and loses yearly by death 4830 men, or nearly five regiments. With respect to the loss and sickness in war, all the evidence goes to show that the diminution in the mortality of men before the mutiny was due to improvements in the sanitary arrangements. Fever, dysentery, diarrhœa, cholera, liver affections, and other diseases which prove specially fatal in India, were referred to in the paper, and numerous statistics furnished as to this effect. Comparative statements of the mortality among officers and civil servants in England and India were also given. The report, in its recapitulations, states that the inquiries of the Commission have shown—1. That by far the larger proportion of the mortality and inefficiency in the Indian army has arisen from endemic diseases, and notably from fevers, diarrhœa, dysentery, cholera, and from diseases of the liver. 2. That the predisposition to these diseases is in part attributable to malaria, in conjunction with extremes of temperature, moisture, and variability. 3. But that there are other causes of a very active kind in India, connected with stations, barracks, hospitals, and the habits of the men, of the same nature as those which are known in colder climates to occasion attacks of the very diseases from which the Indian army suffers so severely.

A Statistical Account of the Parish of Bellingham. *By* W. H. Charlton.

On the Origin of the Stockton and Darlington Railway.
By W. Fallows, *of Middlesbrough.*

The author began by stating that the first locomotive railway was the Stockton and Darlington line, the Act for which was dated April 19, 1821, and the line opened in September 1825; whilst the Act for the Liverpool and Manchester, to which the honour of being first constructed has been erroneously assigned, was dated May 5, 1826, and it was opened September 15, 1830. The first effort to provide for the extension of the trade of the South Durham district was made as early as 1767, when subscriptions were opened for connecting the towns of Stockton and Darlington and the neighbouring country by means of a canal. A joint report on the project was prepared by Mr. Robert Whitworth and the celebrated Brindley, estimating the expense at £63,722, exclusive of parliamentary expenses; the total length was to be thirty-three miles, and the rise in that distance 328 feet. The scheme was never carried out, and similar projects made afterwards met with the same fate. A public meeting was held at Stockton in July 1818, presided over by the Earl of Strathmore, at which, notwithstanding resolutions proposed by Mr. Edward Pease and other gentlemen in favour of the formation of a railway, a canal scheme in the northern part of the district, based on the report of Mr. Leather, was resolved to be adopted. Mr. Pease and his friends called a meeting at Darlington on the 13th November in the same year, when it was resolved to form a Company for a railway from Stockton by way of Yarm and Darlington, to the Auckland coal-field, with a proposed capital of £100,000. The share list was soon made up, and Mr. Overton surveyed the line. An application was made to Parliament for an Act for constructing the same; and such an Act received the Royal assent in April 1821, and George Stephenson was called in to construct it. The first rail was laid by Mr. Meynell (the Chairman of the Company) on the 22nd of May, 1821. The formal opening of this railway took place on the 27th of September, 1825, when a locomotive drawing five waggons laden with coal, one with flour, one containing surveyors, engineers, &c., six waggons with strangers, fourteen with workmen and others, and last of all, other six waggons of coals, passed from one end to the other of the line. The whole train moved at the rate of from ten to twelve miles an hour, with an estimated weight of 86 tons. It was computed that about 700 people were drawn in this train, a number which created the greatest astonishment. Since that time the Stockton and Darlington Railway has always paid dividends to its shareholders; and the Company, having carried into effect the scheme foreshadowed by Brindley and Whitworth, has become the connecting link between the towns of Stockton and Kendal and the western parts of the island. The Company, as a separate company, held its last meeting during the present month (August 1863), Parliament having sanctioned its amalgamation with the North-eastern system. It began with a capital of £100,000, and ended as a separate company with one of £4,000,000.

On the Difference between Irish and English Poor-law. *By* Dr. Hancock.

He said that the difference between the Irish and English Poor-laws was most material. The statistics of the distressed districts show the extent to which able-bodied men can and do get relief. There was a very simple proof that the Irish Poor-law could not be adopted in Ireland. The Poor-law Amendment Act, in 1834, was passed with the intention of abolishing all out-door relief to the able-bodied, but when it began to be extended to the manufacturing districts in the North of England, this was found to be impracticable, and the attempt was given up. The great intercourse which takes place between England and Ireland leads to the labouring population spending part of their lives in one country and part in the other. It is manifest that the establishing of a different rule by law as to the mode of treating labourers engaged in the same trade when suffering from the same calamity, is just such a cause as would be calculated to contribute in some degree to feelings of discontent. There can be no doubt that a great deal of disturbance connected with land in Ireland, particularly the more violent part of it,

has been caused by the attempt of many proprietors to convert the Irish peasant occupiers into farm-labourers, in view of copying what they see in England and Scotland. Those who do so, if they wish to succeed, should carry out the whole of the English system of agricultural management. If they omit such an important element as the Poor-law they cannot expect to be successful—at any rate, it is obvious that Irish proprietors should not be restrained by law from managing the relief of their poor labourers exactly as English proprietors do.

On the Opening and Extension of Durham University Academical Endowments. By JAMES HEYWOOD, *M.A., F.R.S.*

The University of Durham possesses estates, the gross income of which, during the last four years, has averaged £7170 a year, whilst the average net income for the same period has only been £5410 a year. The difference between these two sums, or £1760, shows the average annual outgoings of the property, which amount to nearly one-fourth of the gross rental, and are so excessive, that advantage would be derived by an appeal to the Attorney-General to inquire, by means of the agency under his control, into the cost of the management of the landed estates of the University of Durham, considered as charitable property.

Commissioners were appointed, under the Durham University Act of 1861, for the improvement of that seat of learning; they included the Right Rev. Dr. Baring, Bishop of Durham, the Right Hon. R. Lowe, M.P., the Right Hon. C. B. Adderley, M.P., the Hon. H. G. Liddell, M.P., the Rev. Dr. Vaughan, and Robert Ingham, Esq., M.P.

In their report, the Commissioners observe that the financial arrangements of the University of Durham have been conducted with little system or success; they remark that there has been no sufficient encouragement given to the study of physical science, and that the University of Durham has failed to do for the industry of the North all that it might reasonably have been expected to perform.

The scheme of the Ecclesiastical Commissioners for the University of Durham had originally comprised the annexation of the wardenship of the University to the deanery of Durham, the endowment of the professorships of Divinity and Greek with canonries in Durham Cathedral, and the establishment of twenty-four fellowships of £120 a year each, with a further sum of £30 a year to each of the ten senior clerical fellows.

Among the alterations suggested by the Commissioners of 1861, were the cessation of any further appointments to any of the twenty-four fellowships, all of which had been exclusively limited to members of the Church of England, and the stopping of any further elections to twenty scholarships belonging to the University, and hitherto confined to members of the Church of England.

Forty open scholarships of £30 a year each, to be competed for by any persons, whether members of the University or not, and to be tenable for two years each, were proposed by the Commissioners of 1861, in place of the previous arrangement of fellowships and scholarships; and a further recommendation was made, that forty additional scholarships of £50 a year each should be created, to be competed for by any students commencing their second year, and to be tenable for one year, with the power of a successful candidate retaining such £50 scholarship for an additional year, in any case where the student, having taken a degree in one department of the University, should select to study in some other department of the University; as, for instance, if a scholar, who is a Bachelor of Arts, should choose to study either divinity or physical science.

Under the existing Durham system, about £2916 are annually laid out in fellowships, and £740 in scholarships; the change proposed by the Commissioners of 1861 in this plan has been arrested by petitions from the Dean and Chapter of Durham, and other persons, to the Queen in Council, which have been supported by pleadings before a Committee of the Privy Council, and have led to the disallowance of the ordinances of the Commissioners of 1861 by the Privy Council.

It is not the intention of the Commissioners of 1861 to issue any fresh ordinances, and the work of reform is for the present practically left in the hands of the Dean and Chapter of Durham.

All the students of the University of Durham are expected to attend the Church of England service, and subscription to the three articles of the thirty-sixth canon of the Church of England is expected previous to any degree in Arts being conferred. Dissenters are consequently virtually excluded from the University of Durham.

An almost constant decline is observable in the numbers of the Durham University students. In 1862–63 there were only 23 students in Arts and 23 students in Divinity; total 46 students.

The sums required from the University of Durham endowments, for the scholarships suggested by the Commissioners of 1861, would be £1600 a year, viz., £600 a year to provide for twenty open scholarships of £30 a year each, tenable for two years, and £1000 a year for twenty open scholarships of £50 a year each, tenable for one year; some additional provision would also be needed to meet the case of the £50 scholarships being continued for a second year.

Remarks on Native Colonial Schools and Hospitals, from the Sanitary Statistics of the Aborigines of British Colonies, collected by Miss Nightingale. *Presented to the Statistical Section by* James Heywood, *M.A., F.R.S.*

An inquiry has recently been conducted by Miss Nightingale into British colonial hospitals and schools. That distinguished lady has been assisted by the Duke of Newcastle, Secretary of State for the Colonies, in her important investigations, and a still more extended inquiry is recommended by her into the condition of the ancient tribes who still remain in the British colonial possessions.

Adult natives in many of the colonies are regarded as specially liable to the disease of consumption: diseases affecting the chest may be considered as a main cause of the gradual decline and disappearance of some of the civilized or semi-civilized races of aborigines.

Many of the school-houses for native children are described in the colonial returns as of bad construction, and ill situated for health, and the ventilation is often very insufficient. The period of tuition varies considerably, from two up to ten or more years.

Many returns have been received from hospitals for the native population in the colonies, and the statistics of mortality in these returns show a very high death-rate upon the number received into those institutions. Among the causes of such a mortality may be mentioned, defective stamina in the native population, delay in applying for medical relief, bad and insufficient accommodation, or defective medical treatment, and inadequate management of the sick.

Bad, over-crowded dwellings for the natives, deficient drainage, bad water, want of cleanliness, and other bad habits, must also have their share in increasing disease and mortality.

A select Committee of the Legislative Council of Victoria, Australia, inquired in 1858–59 into the condition of the Australian aborigines, and noticed in their report, that the rapid settlement consequent upon the country being occupied by flocks and herds was more unfavourable to the aborigines than if the land had only been gradually taken up for agricultural purposes.

The Committee were of opinion that great injustice had been perpetrated upon the aborigines, and that when the government of the country found it necessary to take from them their hunting-grounds and their means of living, proper provision should have been made for the natives thus dispossessed of their former territory.

Miss Nightingale recommends the following remedial measures for the native population in the colonies:—

1. Provision of land should be made for the exclusive use of the existing tribes, and settlements should be formed under any Christian denomination which might undertake in a wise manner the gradual winning of the native population under their care to higher and better habits.
2. The prohibition of the sale of intoxicating drinks to the aborigines.
3. The proper conduct of education.
4. Physical training and out-door work.
5. Encouragement of open-air activity.

On the Reduction of the Death-rate in Gateshead by Sanitary Measures. *By* JOHN LAMB.

The situation of the town of Gateshead is upon the banks of the River Tyne, immediately opposite Newcastle—built partly on the low ground adjoining the river, and partly on rapidly rising ground behind, the whole being very favourably situated for drainage. In the old parts of the town, on the flat ground at the river's edge, the streets are narrow, two of considerable length being only from 8 to 10 feet wide; other parts of the old town are built in courts, the houses in almost all cases being improperly constructed, and devoid of all means of thorough ventilation; generally miserably deficient in accommodation, and no yard attached, the whole available space being built upon.

Previous to 1851 (when the Public Health Act was applied to Gateshead), there had only been one sewer executed, costing £2000, but no use was made of it for "private drainage." Sewerage works were commenced by the Board in 1854, and they spent up to the end of 1862 the sum of £6525; but this left about one-fourth of the sewerage works yet to be done to render them complete, or, say, total executed, and to be executed, will cost £10,500. The smallness of this sum for a town of 33,589 inhabitants (in 1861) is owing principally to the favourable nature of the site for drainage, and also in some measure to the cheapness of the materials, the whole of the sewerage pipes being made in the town, and on account of pipes 6 inches diameter being in most cases used for branch sewers instead of 9-inch and 12-inch, the usual sizes.

The cost of draining towns varies from 12*s*. to 20*s*. per head of the population, or even in some cases higher, but the sewerage works of Gateshead will only cost 6*s*. 3*d*. per head.

Since 1851 there has also been executed all necessary "private drains," connecting the houses and yards with the public sewers, costing, say, four-fifths of the public sewers (the usual proportion), or £5000.

Between 1851 and 1862 there have been thirty-six "private streets" paved at an expense to the owners of the adjoining houses of £3680.

The cost of the whole of the above permanent sanitary works executed has therefore been £15,205.

As the result of this expenditure, the annual mortality has been reduced from 30·2 per 1000 (for the six years from 1851 to 1856 inclusive) to 25·4 per 1000 (for the six years from 1857 to 1862 inclusive), or a saving of nearly 5 per 1000. If, instead of the last six years, the average of the last four years were taken, the death-rate will be still further reduced to 24·3 per 1000.

This is far above what it ought to be, as the normal mortality of towns may be stated at 17 per 1000, but which standard it is not anticipated will be speedily reached in Gateshead, on account of the malconstruction of the old houses, as mentioned above. Yet, as new and better houses are built, and sanitary works are vigorously carried on, there is every reason to believe that a mortality of less than 20 per 1000 will be attained.

On the Decrease of the Agricultural Population of England, 1851–61. *By* FREDERICK PURDY, *Principal of the Statistical Department, Poor Law Board, and one of the Honorary Secretaries of the Statistical Society.*

The author commenced by drawing attention to the prosperity which of late years has attended English farming, and to the rise in the value of land, especially since 1853. Nevertheless, at the last census it was found that the only counties which had decreased in population were the agricultural ones of Cambridge, Norfolk, Suffolk, Wilts, and Rutland. To exhibit the decrease in the population ascribed to the class "Agricultural" in the census of occupiers of 1861, the writer divided the kingdom into three sections. (1) 24 counties of *highest* rank, where upwards of 20 per cent. of the adult population is occupied in agriculture. (2) 16 counties of *intermediate* rank, where over 10 and under 20 per cent. is employed; and (3) 5 counties of *lowest* rank, where less than 10 per cent. is employed. Between 1831 and 1861 the first section of counties had increased 1,093,000, or 22 per cent. on the population generally; the second section 1,651,000, or 39 per cent.;

and the third section 3,425,000, or 73 per cent. It was stated that in 1831 the population was pretty equally divided between the three sections: the respective proportions were then 5·0, 4·2, and 4·7. In 1861, however, in consequence of the unequal rate of increase, those ratios became 6·1, 5·9, and 8·1. In 1851, the number of persons in England and Wales, aged 20 years and upwards, occupied in agriculture was 1,576,080; in 1861 the same class had fallen to 1,531,270. This shows an actual decrease of 44,790 persons, or nearly 3 per cent. in the ten years. The greatest decline had taken place in the south-western and the Welsh divisions. In the former, consisting of the counties of Wilts, Dorset, Devon, Cornwall, and Somerset, the decrease was 20,381, or 9 per cent.; and in the latter, which includes Monmouthshire, it was 13,285, or 8 per cent. The ratio of adults engaged in agriculture in England and Wales on the adult population generally in 1851 was 16·1 per cent., and in 1861 it was 13·9 per cent., which is therefore a decline of 2·2 per cent.; in other words, 22 in every 1000 of the adult population had, between 1851 and 1861, ceased to belong to the agricultural class. Mr. Purdy showed that, during the last decade, the falling off in certain counties was very considerable. Sussex had lost 2698; Hants, 3412; Berks, 1158; Herts, 1095; Bucks, 1048; Suffolk, 3306; Wilts, 2837; Dorset, 1343; Devon, 9475; Cornwall, 3917; Somerset, 2809; Gloucester, 1166; Northumberland, 1265; Cumberland, 2099; Monmouth, 1089; South Wales, 4530; and North Wales, 7666. The highest percentages of decrement took place in Devon, 13·3; North Wales, 11·0; Cornwall, 10·5; Hampshire, 8·8; Cumberland, 7·7; Monmouth, 7·6; Wilts, 7·3; Sussex, 6·5; Suffolk, 6·4; Dorset, 5·6; South Wales, 5·6; Hunts, 5·4; Bucks, 5·1; and Northumberland, 5·1. It was observed of Wiltshire that, while the population generally had decreased by 4904, the decrease of the adult agricultural population was 2837; and that in Suffolk the general decrease was only 747, while the agricultural decrease was 3306. Mr. Purdy stated, however, that eleven counties had increased their agricultural population. The six most remarkable instances were these: Salop had increased 1226, or 3·5 per cent.; Worcester, 1281, or 5·7; Leicester, 1371, or 6·0; Lincoln, 2139, or 3·3; Chester, 1550, or 4·2; and Lancaster, 5336, or 7·1 per cent. Attention was directed to the fact that the largest increase had occurred in our great manufacturing county, and further, that Lancashire, in 1861, employed a larger agricultural population than any other county. The number of adults so engaged was 80,822. The West Riding of Yorkshire, which in this respect comes next, only employed 77,168, and Lincoln, a purely agricultural county, 67,357. Though the adult agricultural population of Lincoln is 11,000 less than Lancashire, the return of the farmers' profits (Schedule B.), in 1859–60, in the former county exceeded those of the latter by £1,000,000; the valuation in both counties having been made upon precisely the same principle, that is, by assessing all the farms, whether their occupiers were liable to pay income-tax or not. In 1851 there were in Lincolnshire 10,970 farms, *one-fourth* of the number exceeding 100 acres each; while in Lancashire, with 15,365 farms, less than *one-twentieth* of them exceeded 100 acres each. Excluding from each county those persons placed under the agricultural class, but who in fact work in woods or in gardens, it is found that in Lincolnshire there were 65,849, and in Lancashire 76,496 adults engaged in agriculture properly so called. The Schedule B. valuation of the first county is £2,647,000, and of the second £1,605,000. Dividing these sums among the adults respectively employed in each, gives £38 per head for Lincolnshire, and £21 for Lancashire. The exact relation between the agricultural capacity of the two counties can only be satisfactorily shown when England adopts a system of agricultural statistics like that of Ireland. The diminution of the agricultural population was attributed to emigration, and to the attraction of higher wages in other industries; though a considerable advance had taken place of late years in the money wages of the farm labourer. In Wales, where a large decrease of the agricultural class has been noted, the men's wages had risen from 7*s.* 6*d.* in 1837, to 11*s.* in 1860. Contemporaneously with the general advance of agricultural wages, large tracts of waste land had been enclosed for cultivation. The Enclosure Commissioners state the total area to be 390,000 acres; this is equal in extent to the county of Hertford. The writer concluded by remarking that the want of agricultural statistics in England precluded any investigation of the effect

which the decrease of manual labour may have had upon the productiveness of the soil,—how far increase of skill and mechanical appliances have supplied the place of the labourer,—what and how much did England yield when 1,576,000 of her adults belonged to the agricultural class,—what and how much, ten years later, when the class was reduced by 45,000 persons. These are questions of great interest, but which at present cannot be solved statistically.

The following summary Tables have been compiled from the Statistical Appendix to Mr. Purdy's paper.

A.—Table of the number of Adults engaged in Agriculture in England and Wales in 1851 and 1861, and the proportion to the Adult Population.

Divisions.	Number of persons, aged 20 and upwards, engaged in agriculture.		Ratio per cent. on the total population, aged 20 and upwards.		Decrease in the ratio of 1861.
	1851.	1861.	1851.	1861.	
1. The Metropolis	15,838	15,687	1·1	1·0	0·1
2. South-Eastern	184,601	178,146	20·8	17·4	3·4
3. South-Midland	167,627	163,547	25·4	23·5	2·1
4. Eastern	160,249	155,818	26·5	25·2	1·3
5. South-Western	227,554	207,173	23·3	20·7	2·6
6. West-Midland	179,363	179,800	15·5	13·7	1·8
7. North-Midland	142,389	144,710	21·7	20·7	1·0
8. North-Western	112,184	119,070	8·3	7·4	0·9
9. York	137,681	136,909	14·3	12·5	1·8
10. Northern	83,822	78,942	16·1	12·9	3·2
11. Welsh	164,773	151,488	25·7	21·4	4·3
England and Wales	1,576,081	1,531,290	16·1	13·9	2·2

Note.—The numbers in 1861 are exclusive of persons "employed about animals," that class not being returned as one of the agricultural occupations in 1851.

B.—Table showing the Counties which, between 1851 and 1861, experienced the greatest absolute Decrease in the number of Adults employed in Agriculture.

Divisions.	Counties.	Amount of absolute decrease in 1861.	Ratio per cent. of absolute decrease.
South-Eastern	Sussex	2698	6·5
	Southampton	3412	8·8
	Berkshire	1158	4·0
South-Midland	Hertfordshire	1095	4·6
	Buckinghamshire	1048	5·2
Eastern	Suffolk	3306	6·4
South-Western	Wiltshire	2837	7·3
	Dorsetshire	1343	5·6
	Devonshire	9475	13·3
	Cornwall	3917	10·5
	Somersetshire	2809	5·0
West-Midland	Gloucestershire	1166	3·2
Northern	Northumberland	1265	5·1
	Cumberland	2099	7·7
Welsh	Monmouthshire	1089	7·6
	South Wales	4530	5·6
	North Wales	7666	11·0

*** Mr. Purdy's paper upon the decrease of the agricultural population of England will be found in the Journal of the Statistical Society for 1864 *in extenso.*

On the Mortality of Lancashire, &c., during the year ended at Midsummer 1863. *By* Frederick Purdy, *Principal of the Statistical Department, Poor Law Board, and one of the Honorary Secretaries of the Statistical Society.*

This was a continuation of the paper which the writer brought before the Section at Cambridge. The cotton famine was felt in several of the Lancashire unions through a marked increase in pauperism at the beginning of 1862. It increased till the Midsummer following, when the distress had assumed most serious proportions, which continued to augment still more rapidly up to December, when the maximum of destitution was reached; thence to Midsummer last it has steadily declined, leaving, however, in the unions principally affected, a rate of pauperism which is between three and four times their normal ratio. The deaths in Lancashire during the year ended Midsummer were compared with the average of the three years ended at Midsummer 1862. The average was 61,263; last year's deaths 64,828, being an increase of 3565, or 5·8 per cent. No attempt was here made to correct the figures for the increase of population. A similar comparison was made for three contiguous divisions—Yorkshire, where the deaths were respectively 46,454 and 49,955, being an increase of 3501, or 7·5 per cent; the rate of increase was here larger than in Lancashire,—the Northern division, deaths 25,499 and 26,876, which showed an increase of 1377, or 5·4 per cent., very close to the Lancashire rate of increase,—and the North Midland division, deaths 26,578 and 25,181, which showed a decrease of 1397, or 5·3 per cent.

Limiting the inquiry to the principal cotton manufacturing unions, properly so called, a group of sixteen was formed of the most distressed. The two first belong to Cheshire, the others to Lancashire. They are the unions of Stockport, Macclesfield, Wigan, Bolton, Bury, Chorlton, Salford, Manchester (with Prestwich), Ashton-under-Lyne, Oldham, Rochdale, Haslingden, Burnley, Blackburn, and Preston. The average number of deaths in the three years was 43,152, and the deaths in the year ended Midsummer last, 43,951, that is to say, an increase of 799, or 1·9 per cent., as compared with the average. But it was found, on correcting the numbers with respect to the increase of population, that the average should be 42,353, the deaths for the year ended Midsummer last, 41,574; this then exhibited, instead of an increase, a decrease of 779 deaths, or 1·8 per cent.

The sixteen unions were arranged in three sections, as in the Cambridge paper.

Section A. contained 7 unions, which at Midsummer 1862 were least pauperized; the increase of pauperism as against 1861, was at that time 34 per cent. in the lowest burthened, and 100 per cent. in the highest. It was shown, by comparison of the deaths in the year ended Midsummer 1863 with the average of the three preceding years, that Wigan, Chorlton, and Oldham had increased 8·7, 13·9, and 16·9 per cent. respectively; that Macclesfield, Salford, Bolton, and Bury had decreased 5·0, 0·9, 2·2, and 4·1 per cent. respectively.

Section B. consisted of 4 unions; the increase of pauperism at Midsummer 1862 varied in this section from 120 to 145 per cent. The deaths in Manchester (with Prestwich) had increased 2·7 per cent. The others had decreased: Rochdale, 6·6 per cent.; Burnley, 16·0 per cent.; and Haslingden, 1·6 per cent.

Section C. was formed of 4 unions; the pauperism had increased from 283 in the lowest union to 458 per cent. in the highest. Stockport had increased in deaths 12·0 per cent., and Ashton-under-Lyne, the most distressed union in the whole district, judging by the numbers on the books of the relieving officers and of the Relief Committees, 3·9 per cent.

In the Preston union there was a decrease of 8·7 per cent. in the deaths. This union felt the distress earlier, and till it was surpassed by Ashton, heavier than any other. Last autumn typhus fever prevailed at Preston. Dr. Buchanan, the Government Inspector, who visited the district, reported the fever as "the steady follower on famine," and gave, it may be remembered, a very gloomy account of the physical depression of the unemployed operatives generally; yet in the very year of this fever, which disease soon disappeared, there were 256 less deaths in the union than on the average of the three preceding years. Blackburn, also a very distressed union, shows a slight decrease of mortality. Liverpool, though

the largest cotton port in Europe, has been but slightly affected by the cotton famine; the pauperism there is, and has been, but little in excess of its usual amount. It has not been found necessary to institute any Relief Committees. Nevertheless the increase in the death-rate has been very great. The average number of deaths in the three years was 8198; in the year ended Midsummer 1863 it was 9475, being an increase of 1277, or 15·6 per cent. In the contiguous union of West Derby, the deaths were respectively 4915 and 6199, increase 1284, or 26·1 per cent. These figures present a remarkable contrast to the average death-rate of the cotton manufacturing unions during the same period. Mr. Purdy observed that the increase of mortality in the Manchester, Ashton-under-Lyne, Chorlton, Oldham, and Wigan unions appeared from the Registrar's Returns to have been caused by the prevalence of epidemics in those districts, especially from scarlatina, diphtheria, measles, and small-pox. The decrease of deaths in the other unions has been attributed by various Registrars to the generally temperate state of the weather; to the change from employment in the atmosphere of the mills to the open air; and to the greater maternal care bestowed upon the younger children. The possible saving of life from the last-named cause may be very great indeed, when it is remembered that *one-half* of the large mortality of the Lancashire towns is usually that of children *under five years of age*.

The Tables which follow have been extracted from the Appendix to the original paper.

Section A.—Unions of least Pauperism.

Unions.	Increase per cent. in Paupers at Midsummer and Christmas 1862, compared with 1861.		Number of Deaths.		Difference per cent.
	Midsummer 1862.	Christmas 1862.	Average of three years ended Midsummer 1862.	The year ended Midsummer 1863.	
Macclesfield	34	40	1486	1412	− 5·0
Salford	84	215	2614	2590	− 0·9
Bolton	41	136	3440	3363	− 2·2
Wigan	38	121	2391	2599	+ 8·7
Bury	100	343	2353	2256	− 4·1
Chorlton	68	464	3735	4255	+13·9
Oldham	86	497	2774	3243	+16·9

*** The Unions are arranged, in this and the two next Tables, according to the ratio of paupers to population at Christmas 1861: the most pauperized at that date is placed first. (See previous paper, 1862.)

Section B.—Unions of medium Pauperism.

Unions.	Increase per cent. in Paupers at Midsummer and Christmas 1862, compared with 1861.		Number of Deaths.		Difference per cent.
	Midsummer 1862.	Christmas 1862.	Average of three years ended Midsummer 1862.	The year ended Midsummer 1863.	
Manchester with Prestwich	127	340	7228	7421	+ 2·7
Rochdale	120	414	2111	1971	− 6·6
Burnley	145	348	1835	1541	−16·0
Haslingden	108	431	1529	1505	− 1·6

Section C.—Unions of highest Pauperism.

Unions.	Increase per cent. in Paupers at Midsummer and Christmas 1862, compared with 1861.		Number of Deaths.		Difference per cent.
	Midsummer 1862.	Christmas 1862.	Average of three years ended Midsummer 1862.	The year ended Midsummer 1863.	
Preston	283	231	2951	2695	− 8·7
Blackburn	322	348	2952	2931	− 0·7
Stockport	306	299	2324	2605	+12·0
Ashton-under-Lyne	458	224	3429	3564	+ 3·9

Section D.—Unions of ordinary Pauperism.

Unions.	Increase per cent. in Paupers at Midsummer and Christmas 1862, compared with 1861.		Number of Deaths.		Difference per cent.
	Midsummer 1862.	Christmas 1862.	Average of three years ended Midsummer 1862.	The year ended Midsummer 1863.	
Liverpool	8	3	8198	9475	+15·6
West Derby and Toxteth Park	8	1	4915	6199	+26·1

Statistics of the Tanning Trade of Newcastle-upon-Tyne.
By the late T. C. Angus. *Communicated by* James Potts.

Thirty years ago Newcastle appears to have taken the lead in the tanning trade, but now Leeds occupies that position. The present state of the tanning trade in Newcastle and Gateshead is represented by the following statistics:—

		Value about		
Bark used during the year 1862,	1780 tons	£9753	0	0
Valonia " "	154 "	2202	0	0
Gambier " "	50½ "	980	0	0
Divi divi " "	55 "	772	0	0
Shumac " "	314 "	4315	0	0
Oil, Cod, and Linseed "	118 "	5310	0	0
Lime and Pigeon-dung		324	0	0
Tallow		100	0	0
Dyes		800	0	0
Striping materials		100	0	0
Eggs		600	0	0
Alum and Soda		200	0	0
Dogs' Manure		280	0	0
		£25,736	0	0

Raw Materials put into Work.

Butchers' hides,	38,020	713 tons	£24,908	0	0			
Calf-skins	62,124	84 "	9,320	0	0			
Sheep-skins	46,452		2,322	0	0			
Seal-skins	163,000	873 "	40,750	0	0—	77,300	0	0
						£103,036	0	0

The above will produce in value when manufactured—

Butchers' hides	£47,500	0	0			
Calf-skins	16,373	0	0			
Sheep-skins	3,871	0	0			
Seal-skins	67,915	0	0—	£135,659	0	0

Comparison of the Organization and Cost in detail of the English and French Statistical

The following is the analysis of the paper, to which is added the pay tables

English Army.

Effectives.	Number.	Cost.	Cost per head.
		£	£ s. d.
1. Effective and non-effective services...	148,242	15,060,237	101 11 10
Deduct charges for auxiliary forces disembodied militia, enrolled pensioners, and volunteers	—	1,222,977	
		13,837,260	93 6 10
2. Effectives and non-effectives	148,242	13,837,260	
Deduct from charges, the non-effectives	—	2,127,836	
		11,709,424	78 18 5
3. Infantry pay	102,765		
Cavalry "	13,867		
Artillery "	23,740		
Engineers "	4,906		
Military train pay......................	1,840		
	147,118	4,967,603	33 15 3
4. Administration of the army............	148,242	164,917	1 2 3
Secretary of State for War, Commander-in-Chief's department ...	148,242	48,260	
Total	—	213,177	1 8 0
5. General staff	148,242	114,976	0 15 6
6. General staff, Commander-in-Chief, &c.	261	79,476	304 5 0
7. War Office, Secretary of State for War.	1	5,000	5000 0 0
Other officers	531	153,446	288 19 0
8. Infantry of the line, officers, and men.	81,300	2,479,600	30 1 0
9. Cavalry of the line	10,826	448,980	41 9 8
10. Engineers	4,906	277,142	56 9 9
11. Artillery, horse and foot, including 1882 at the depôt............	22,372	870,602	38 18 3
12. Military train...........................	1,840	71,381	38 15 4

Armies for 1863–64. *By* Colonel Sykes, *M.P., F.R.S., President of the Society.*

of the French and English armies.

French Army.

Effectives.	Number.	Cost.	Cost per head.
		fr.	£ *s.* *d.*
1. Effective and non-effective services	400,000	434,624,040	43 11 10
Deduct dotation	—	63,340,000	
2. Effectives	400,000	371,284,040	37 2 6
3. Infantry pay	244,023		
Cavalry ,,	59,679		
Artillery ,,	37,873		
Engineers ,,	7,809		
Military train pay	3,655		
Petiranâs pay	64		
	353,103	147, 01,500	16 13 4
4. Administration central personal	400,000	1 910,538	0 5 1
,, ,, material		549,500	
Depôt general of war		144,500	
		2,604,538	0 5 5
5. Etat-major or staff	400,000	21,280,287	2 2 6
Includes sub-officers and clerks	4,655		183 0 0
6. Etat-major, 1st article, marshals of France, &c.	794	8,688,080	438 0 0
7. War Office, Minister of War	1	130,000	5,200 0 0
Other officers	479	1,643,998	137 6 8
8. Guard imperial	17,784		
Infantry of the line in France	199,992		
,, ,, Algeria	26,247		
Total	244,023	90,629,169	14 17 6
9. Cavalry of the ine	53,175	24,043,056	18 1 8
10. Engineers	6,968	2,937,936	16 18 4
11. Artillery, horse and foot	37,873	17,350,464	18 6 8
With subscriptions and indemnities the cost is	—	19,326,017	20 8 4
12. Military train	4,722	2,316,721	19 3 4

TABLE (*continued*).

English Army.

Effectives.	Number.	Cost.	Cost per head.
		£	£ s. d.
13. Army hospital corps	940	23,510	25 0 2
14. Medical establishment	148,242	281,260	1 17 11
15. Commissariat charges	148,242	1,223,936	8 5 2
Fuel and light for the barrack department	148,242	278,537	1 17 7
			10 2 9
16. Clothing, &c., and establishment	139,630	630,385	4 10 3
17. Barracks and establishment, &c.	148,242	635,637	4 5 0
18. Martial law	148,242	43,012	0 5 9
19. Manufacturing department	148,242	956,365	6 9 0¼
Warlike stores		838,369	5 13 6
			12 2 6¼
20. Small arms factory	148,242	181,944	
„ „ purchase and repair		105,769	
		287,713	1 18 9
21. Gunpowder factory	148,242	75,617	
Purchase ditto and saltpetre		733,658	
		809,275	1 8 2½
22. Royal gun factory and materials alone	148,242	127,280	0 17 2
Purchase of iron ordnance, &c.		124,233	
		251,513	1 13 11
23. Purchase of horses:			
Veterinary establishment	Total horses 14,511	3,921	
Horses and medicine		32,493	
		36,414	2 10 3
24. Military education	148,242	172,201	1 3 2½
25. Barracks at home	148,242	635,637	4 5 9
Works and buildings, and barracks at home and abroad	148,242	810,941	5 9 4½
		1,446,578	9 15 1½
26. Non-effective services	148,242	2,127,838	14 7 1

The differences in the departmental organization of the English and French approximation to truth in all cases.—W. H. SYKES.

TABLE (*continued*).

French Army.

Effectives.	Number.	Cost.	Cost per head.
		fr.	£ s. d.
13. Military hospitals	4,573	4,921,884	43 0 10
14. Medical establishment	400,000	14,753,650	1 10 8
15. Commissariat, provisions, forage, light, and warming..............	400,000	68,772,140	6 18 4
16. Clothing and the establishment......	336,626	16,157,700	1 19 11
17. Beds and bedding, furniture, &c.	400,000	6,576,961	0 13 $6\frac{1}{2}$
Infantry buildings, repairs, &c. &c.	—	10,536,090	
		17,113,051	1 15 7
18. Justice militaire	400,000	1,260,987	0 2 6
19. Manufacturing department and warlike stores	400,000	26,769,010	2 13 $11\frac{1}{2}$
20. Small arms for 1861	400,000	2,060,000	
„ „ repairs, purchase, &c.		1,449,230	
		3,509,230	0 7 $3\frac{1}{2}$
21. Gunpowder establishment and materials	400,000	8,391,465	0 17 6
22 Foundries..............................	400,000	638,000	0 1 3
Forges		420,000	
		1,058,000	0 2 1
23. Cost of purchase of remount horses and mules	85,705	5,429,250	2 10 10
24. Military education	400,000	3,004,033	0 7 1
25. Buildings and fortifications by the engineer corps and department	400,000	10,951,890	1 2 $6\frac{1}{2}$
26. Non-effective services, Hôtel des Invalides, compassionate allowances to old soldiers, the widows and orphans, and to wounded soldiers	400,000	4,555,002	0 9 $2\frac{1}{2}$

armies does not admit in some cases of exact comparisons, but there is a satisfactory

TABLE (*continued*).

French Military Pay.

	Guard Imperial Grenadiers.			Chasseurs of the Line.			Infantry of the Line.		
	Yearly pay.	Daily pay when stationary.	Daily pay when on the march.	Yearly pay.	Daily pay when stationary.	Daily pay when on the march.	Yearly pay.	Daily pay when stationary.	Daily pay when on the march.
	fr.	fr. c. m.	fr. c. m.	fr.	fr. c. m.	fr. c. m.	fr.	fr. c. m.	fr. c. m.
Etat-major Colonel ...	7975	22 15 2	27 15 2	......	......	......	5500	15 27 1	20 27 7
Lieut.-Colonel	6235	17 31 9	22 34 9	......	......	......	4300	11 94 11	16 94 4
Major	5220	14 50 0	18 50 0	3600	70 0 0	14 0 0	3600*	10 0 0	14 0 0
Captain, 1st class	4200	12 66 6	14 66 6	2400	6 66 6	9 66 6	2400	6 66 6	9 66 6
,, 2nd ,,	3500	9 72 2	12 72 2	2000	5 55 5	8 55 5	2000	5 55 5	8 55 5
Lieutenant, 1st class ...	2930	8 13 8	10 63 8	1600	4 44 4	6 94 4	1600	4 44 4	6 94 8
Lieutenant, 2nd class ...	2655	7 37 5	9 87 5	1450	4 2 7	6 52 7	1450	4 2 7	6 52 7
Sub-Lieut. or Ensign......	2475	6 87 5	9 37 3	1350	3 75 0	6 25 0	1300	3 75 0	6 25 0
Serjeants	......	1 30 0	1 95 0	......	0 80 0	1 15 0	......	0 80 0	1 15 0
Corporals	......	0 86 0	1 41 0	...	0 46 0 0 41 0	71 0	......	0 46 0	0 71 0
Privates	......	0 65 0	1 10 0	...	0 30 0 0 25 0	55 0	......	0 30 0	0 55 0
Boys under 14...	......	0 43 0	0 73 0	......	0 25 0	0 45 0	......	0 25 0	0 45 0
,, above 14...	......	0 65 0	1 10 0	......	0 40 0	0 65 0	......	0 40 0	......
Surgeon-Major 1	6525	18 82 5	22 12 5	4500	12 50 0	16 50 0	4500	12 50 0	16 50 0
,, 2	4900	13 61 1	16 61 1	2950	8 19 4	11 19 4	2950	8 19 4	11 19 4
,, under 1	3670	10 19 4	12 69 4	2000	5 55 5	8 5 5	2000	5 55 5	8 5 5
,, ,, 2	3300	9 16 6	11 66 6	1800	5 0 6	7 50 0	1800	6 0 0	7 50 0

* All troops of the line have extra pay while in Paris.

Note.—From the "Aide-Mémoire," by V. Milet, Lieutenant, 38th regiment of the line, edition of 1860.

The French military pay is in francs, centimes, and millièmes.

Observations on Criminals.

By THOMAS ROBINS, *Governor of Newcastle-upon-Tyne Jail.*

The importance of this subject is attested by the fact that in the year 1860 no less than 100,614 persons were committed to the prisons in England and Wales, involving a cost of £533,407 18*s*. 8*d*.

In considering the causes of crime, drunkenness, because a ready and plausible reason, is frequently assigned as the sole cause of crime; now, though a most detestable vice, and justly punished *as a crime*, it is, though an important one, but one among *many* causes. It is often the proximate cause of the lighter class of misdemeanors; but the serious crimes of theft and violence are more frequently committed without the stimulus of drink, with well-arranged plans, and under circumstances requiring great self-control.

TABLE (*continued*).

English Military Pay.

Grenadier Guards.				Regiments of the Line.				
Yearly pay.	Yearly pay.	Daily pay.	Daily pay.	Yearly pay.	Yearly pay.	Daily pay.	Daily pay.	
£	fr.	£ s. d.	fr. c.	£ s. d.	fr.	£ s. d.	fr. c.	
2200 0 0	55,000	6 0 1	150 0	1000 0 0	25,000	2 14 9	68 50	Etat-major Colonel.
488 3 9	12,304	1 6 9	32 10	310 5 0	7,756	0 17 0	20 1	Lieut.-Colonel.
469 15 0	10,074	1 3 0	27 60	292 0 0	7,500	0 16 0	19 20	Major.
282 17 6	6,808	0 15 6	18 60	212 10 6	5,076	0 11 7	13 90	Capt., 1st class. „ 2nd „
132 6 0	3,175	0 7 4	8 80	118 12 6	2,846	0 6 6	7 80	Lieutenant, 1st class. Lieutenant, 2nd class.
100 7 0	2,408	0 5 6	6 60	99 16 3	2,395	0 5 3	6 30	Sub-Lieut. or Ensign.
—	—	0 2 2	2 60	—	—	0 2 0	2 40	Serjeants.
—	—	0 1 5	1 70	—	—	0 1 4	1 60	Corporals.
—	—	0 1 1	1 30	—	—	0 1 0	1 20	Privates.
—	—	—	—	—	—	—	—	Boys under 14. „ above 14.
411 10 0	9,636	1 2 0	26 40	273 15 0	6,517	0 15 0	18 0	Surgeon-Major 1.
273 15 0	6,570	0 15 0	18 0	—	—	—	—	„ 2.
182 10 0	4,380	0 10 0	12 0	182 10 0	4,380	0 10 0	12 0	„ under 1.
—	—	—	—	—	—	—	—	„ „ 2.

When we find that of the 100,614 criminals upwards of 8000 were under 16 years of age, it must be obvious that the mass of our criminals commence their career in childhood, before an appetite for intoxicating drink has been formed. The hideous features of the criminal mind show too plainly that bad training is the fruitful source of crime. As the young criminal, whose inheritance is poverty, filth, and a corrupt example, left in brutal ignorance, grows up and exhibits the natural vanity, violent temper, sensuality, and selfishness, by which he is generally distinguished, in an exaggerated form, he is shunned by the respectable, who shrink from even giving him employment; this is too eagerly made an excuse for indulging in idleness, which rapidly leads to crime. There is another class of criminals formed of the waifs and strays of families in better circumstances, who, in spite of parental care and some education, become the victims of idleness and sensuality.

The amount of positive ignorance in the majority of criminals is almost inconceivable: of the 100,614 alluded to, 34,279 could neither read nor write; 61,233

could read or write imperfectly, leaving less than 5000 who had acquired a very moderate amount of education: this ignorance extends also to any occupation they may have followed, however humble.

It is clearly the duty of society to provide asylums for orphans, and enforce the education of all classes for some useful future course in life.

Labour is the true foundation upon which any plan of prison discipline should be based; it should have been one of a prisoner's earliest lessons, and should form one of the leading features of his education; by habitual industry, the mind is more likely to be fitted to receive religious impressions. If reformation be the object sought, prison discipline to be the means, some provision must be made for the employment of prisoners when discharged; this has been successfully tried in London, Wakefield, and Birmingham. No prison of any importance should be without a workshop outside, where men could, after discharge, if willing, fit themselves for the labour-market; thus, in a practical form, would the element of hope, too long excluded from our systems, be introduced, and remove the prisoner's ready excuse of not being able to find employment. With reference to the treatment of prisoners when in prison, any one who will take the trouble to examine the subject thoughtfully, will be satisfied that the popular notion that prisoners are pampered is, generally speaking, a mistake; at the same time, it does appear necessary that the law and the executive power should be shown to be strong enough to deal with the monster evil, and prevent panics such as we lately witnessed.

In managing a great number of convicts, two things are absolutely essential as a foundation: first, that they should be so completely separated from the world as to make escape almost impossible; secondly, that they should be so subdivided as to prevent dangerous conspiracies. This could be effected by planting convict depôts on islands off our own coasts, the prisoners being placed in a number of *small prisons,* all subject to one governor, who, from a central residence, might have telegraphic communication with each, and thereby be enabled, in case of necessity, to concentrate upon any given point an overwhelming force. The separate prisons would also be useful for classification, in some of which a severe discipline could be brought to bear upon the worst class, while the others might be arranged for testing different kinds of discipline, and to suit the different stages of the prisoners in their progress towards reformation; by this plan the deterrent and reformatory principles may be worked out in their integrity with very little increased cost, except at the first for the buildings. None should leave the island, except by the gate of reformation, until their sentences were expired. It would be a mercy to the sick to keep them, whether they live or die, where they could have both spiritual and medical assistance, rather than allow them to return to the corrupting scenes of their vile haunts.

It will scarcely be denied that a responsibility rests upon society with regard to this question, and that the public should be prepared to help the penitent, as well as to punish the incorrigible.

On the Paris Improvements and their Cost.
By W. Tite, *M.P., F.R.S., &c.*

After some general remarks upon the necessity that existed for the alteration of the communications in the centre of Paris, and upon the strategical motives that had led to their adoption, the author of this paper proceeded to consider the question of the cost of those improvements, which he had been informed had been less than that of similar operations in this country. He stated that his impression was, that town improvements could never be executed at a less cost than 70 per cent. of the total outlay; and the result of his examination of the accounts that were presented by the Prefect of the Paris improvements had only confirmed him in that opinion. Instead of yielding a profit to the city, as had been pretended, they had in all cases involved it in great and serious loss.

Mr. Tite dwelt upon the encouragement that the Government of France had thought proper to bestow upon the course that the city had entered into in this matter, by undertaking a portion of the expense, and by authorizing the raising

loans by the city of Paris. The sum that the city was authorized to borrow in this way was as much as 180,000,000 francs; nor would this in all probability be all, for M. F. de Laysterie said (in 1861) that Paris had incurred a total liability of 312,000,000 francs for the indemnities of the proprietors whose houses had been taken, up to that time; and there were other sources of expense and further outlays for the liabilities since undertaken. The Imperial Government had also, according to the Prefect's report, paid the city the sum of 40,500,000 francs as its proportion of the accounts of the works that had been then settled; and it had, in fact, encouraged the city in every way to undertake the duty of remodelling the thoroughfares of the metropolis. The consequence was that Paris had been changed in its external characteristics, as though by magic; the narrow, tortuous streets had made way for long, straight, wide boulevards, parks, &c., for the recreation and the health of the people; but it remained to be seen at what expense to the inhabitants of the city all this was accomplished, and at what expense to the nation.

The accounts of several of the works were not yet made up, but from the Prefect's statement to the Town Council of Paris, it was easy to separate the cost of the Halles Centrales, the Rue de Rivoli, and the Boulevard Sebastopol of the right bank of the Seine. Now, of these, the operation of the Halles Centrales was more exclusively a municipal improvement than such a one as concerned the State, and it ought therefore to be compared rather with the removal of Fleet Market than any analogous work in our country; the State also did not enter into the expense of this operation in any way. The cost of the transfer of the Halles to their present position had been, however, as follows:—the outlay incurred for the purchase of land and the erection of buildings had amounted to the gross sum of 31,796,238·61 francs, of which the city had received, for the sale of waste lands, old materials, and properties unsold, capitalized at thirty-three years' purchase on the rents, the sum of 6,723,071·24 francs; so that it will finally be a loser by this operation of 25,073,167·37 francs, or about 80 per cent.

The Rue de Rivoli was more decidedly of the character of a city improvement than the Halles Centrales, for it served to put in communication with one another, the Tuileries, the Palais Royal, the Louvre, and the Hôtel de Ville; whilst it formed the great artery for the traffic of Paris from the east to the west of the town. The cost of this operation had been about the gross sum of 108,658,000 francs, from which the city derived, for the sale of the surplus land and the old materials, &c., the sum of 34,153,320 francs, thus making the net cost equivalent to 71,504,800 francs. The State intervened for various sums in the result; that is to say, it contributed in some cases one-half, in some two-thirds, and in some one-third of the outlay; so that the total amount of its contribution for the expense of this street was equal to the sum of 20,740,967·27 francs. This reduced the cost of making the Rue de Rivoli to the city of Paris to about 50 per cent. on the total outlay; but it did not affect the real results of the operation, which were, that it cost the nation the proportion of 68·57 per cent. of the outlay.

As to the expense incurred upon the Boulevard Sebastopol, on the portion comprised between the Strasbourg Railway Station and the Place du Châtelet, the city of Paris had incurred the outlay of 58,648,665·80 francs. Upon this sum it had received the amount of 23,880,412·63 francs for the sale of old materials, surplus land, &c.; so that the operation showed a total loss of 34,768,153·17 francs, or about 60 per cent. of the total outlay. The State, however, intervened to the extent of one-third of the loss, which will reduce the portion that will be incumbent on the city of Paris to the net sum of 23,178,856·10 francs, or about 40 per cent. of the total cost. But it is to be observed that in all the above calculations the interest upon the money is not taken into account, though it runs from the day of the jury having given their verdict.

The accounts for the remaining works that have been undertaken for the improvements of Paris have not yet been made up, as was said before, but enough of them is known to enable any one to reason as to their probable cost, which will clearly be in the same ratio as those of the Rue de Rivoli and the Boulevard Sebastopol. Indeed, the works that have been rendered necessary by the Boulevards Malesherbes and Prince Eugène, the streets round the new Opera, the Rue de

Rouen, the Rue Lafayette, the new streets and boulevards on the island of the Cité, and the left bank of the Seine, must have entailed a very considerable expense for levelling the ground, and the works that are required to make the approaches. The same principle has also been adopted in them as in the parts already undertaken; and the quantity of land abandoned for the use of the public was very large. Mr. Tite also incidentally alluded to the outlay that the town had incurred in the laying out of the Bois de Boulogne, the Parc Monceaux, the Bois de Vincennes, the squares of St. Jacques la Boucherie, the Place du Conservatoire, the Palais des Thermes, which he admired very much, but which he considered it would be impossible to execute with a municipal body elected by the people who paid for them.

Mr. Tite stated that he had applied, through Parliament, for the statistics of the improvements of the city of London, but he had not succeeded in obtaining them; all that he had been able to learn was, that the New Cannon Street had cost £589,470, or about £506 per yard forward, and the New Victoria Street £330,675, or about £300 per yard forward; but he had not been able to ascertain what the City had derived from the sale of the land, old materials, &c., in either case. He, however, stated that his experience in this matter was, that the expense attending the conversion of inhabited house-rent to ground-rents was always an operation that was costly in its nature, whatever improvement might be made in the character of the houses; and he was disposed to consider the loss of this operation, which must always be incurred when town improvements are undertaken, was about 70 per cent. of the outlay. The results of the operations in Paris only confirmed him in this opinîon.

Mr. Tite finished his paper by calling attention to the means that the city of Paris adopted to meet the calls that were thus made upon it, and for the current expenses of the town. He showed that the ordinary budget of the town was 112,536,778·08 francs, of which the Octroi duties constituted the major part, they being 83,325,816 francs; the extraordinary budget brought this total to 119,935,272·91 francs, and the supplementary receipts, including the proceeds of the loan, swelled the total sum to 199,807,203·20 francs. From this he concluded that great caution ought to be observed in increasing the debt of Paris, which already had to provide the sum of 10,546,788·64 francs for the interest of that debt.

Mr. Tite, in conclusion, warmly acknowledged his obligations to His Excellency Lord Cowley and the Prefect of the Seine, Baron Haussman, for the valuable documents which had enabled him to prepare this paper.

MECHANICAL SCIENCE.

On an Improved Caisson Gate. By Admiral Sir Edward Belcher.

The floating dock-gates proposed were constructed similar to caissons now used in the royal yards, but in this instance in pairs hinged at the apex, thus facilitating the insertion of the bearing ends into the abutting cavities. They thus form together a complete arch, more effectual the greater the resistance or external pressure may be against the ingress of water. In undocking, those caissons could be attached under the counter of a vessel, and act as a lift, should there be any want of water to float her out.

A brief Description of a Spirit-level Telescope for observing Altitudes and obtaining Latitudes independently of natural or artificial Horizons. By Admiral Sir Edward Belcher.

The telescope is fitted similarly to the transit telescope, with an oblique diaphragm for illuminating the wires. But in this instrument, which has no Y supports, or axis for illumination, the light is reflected through a slit in the upper side, which carries a transparent level tube. The bubble brought into contact with

the centre wire gives a true level gauge; and the sun or other object being brought into contact by the radius bar of the sextant, the altitude is necessarily obtained. The telescope occupies precisely the same position as that used in any ordinary sextant; and practice, even at sea, soon renders the operation easy. On shore, where the sextant can be used with a stand, it will be found very useful for measuring altitudes of objects of small arc, which could not be reflected in an artificial horizon.

On a Mode of rendering Timber-built Ships Impregnable and Unsinkable under Moderate Crew Power, as in Leaky Vessels. By Admiral Sir EDWARD BELCHER.

Referring to a pamphlet by Mr. Walters, who proposed to effect his object by introducing copper cylinders between the timbers, the hold-beams, and indeed every opening where cargo did not prevent—calculating that these displacements or cells would about compensate for difference of specific gravity between cargo, vessel, and gear, so as to simply reduce her to the state of a water-logged craft, to save crew, vessel, and such portions of cargo as might be secured in air-tight vessels—the author stated that the pneumatic trough had suggested to him the propriety of close sealing the holds, or underplanking the hold-beams, and saving those spaces between them for the storage of light dry goods above that deck (which was generally lost), and placing loose planks as a temporary deck. In the event of a dangerous leak, or even a large hole being stove in the bows or bottom of a ship, he proposed securing the hatches from beneath to hatches above, screwed firmly in opposition to each other, and filled in by pitch from the upper or open hatch. It would be apparent that, if the ship was air-tight, the water could only enter so long as the air was compressible; and, by inverting the pump-boxes and rendering them air-pumps, the leak would not only be stopped, but, by the continued action of the air, it would be expelled by the very orifice by which it entered. Therefore the customary and continued labour and wear of the power of the crew would not be required to such an extent, if at all, when once the necessary quantity of air had been forced in.

On the Decortication of Cereals. By ROBERT DAVISON.

After giving a description of the structure of a grain of corn, the author showed the advantages that are to be obtained by decortication; he then dealt with it in a hygienic point of view, and detailed the several qualities of bread made from it, and furthermore stated that it is better to make a quality with *all* flours united, as in this way can a wholesome and well-flavoured bread be best obtained. The author then stated the principle adopted by Mr. Poissant (the pioneer of this system) in order to obtain the complete decortication. He observed, as a singular and important fact, that corn having undergone this process was not so likely to be attacked by that destructive insect, the weevil—that is, if the corn is carefully excluded from the sunshine. The author thus concluded his paper:—1. Decorticated grain will always be profitable to the world, as it incontestibly yields 10 to 12 per cent. more flour than ordinary millering. 2. It can be done in either small or large quantities, and not only produces from 10 to 12 per cent. more flour, but at the same time from 5 to 6 per cent. more glutinous nourishment. 3. It renders corn safe from the attack of the weevil, and therefore renders it more fit for storing against periodical seasons of scarcity. Lastly, the machines are simple, cheap, lasting, and capable of being worked either by hand or motive power, at small cost; and the system has, in fact, no known drawback, except that pollard, bran, &c., which are produced by the present method of millering, will no longer be an article of commerce. But, as a set-off, the pellicle which is produced by the new system is found to make an excellent vellum-like paper, which is largely sought after in France by bookbinders.

On Improvements in Machinery and Apparatus for Cleansing and Purifying Casks. By ROBERT DAVISON.

In the paper which the author read before the Association in the year 1849 on the "Desiccating Process," he took occasion to mention its application to the purifying of brewers' casks, one million having at that time undergone the process; but it had not been made clear that they had a previous operation performed on them—namely, that of cleansing—which was effected by machinery of peculiar construction, the first of which was introduced in 1843 by the author, in concert with Mr. W. Symington. These machines still continue in high repute; but there is, however, one objection—they are only calculated to cleanse one cask at a time. His new process is as follows:—The machine consists mainly of two circular discs, with an upright shaft or spindle in the centre, which has a screw at each end (the threads being cut right- and left-handed); the two discs have, likewise, each a corresponding female screw, which, when turned round on the upright spindle (the same being temporarily fixed), it will be easy to see, will cause the discs to advance or recede from each other, according as they are turned to the right or left hand. Such is the mode by which the casks are secured or released from the machine—that is, by turning in one direction the casks are effectually secured between the two discs, by turning the reverse way they are released. Any number of casks which the bottom disc will contain, and even a second tier (if desired), can be fixed and afterwards cleansed at the one operation—say, two sets of five or ten casks. The best cleansing medium is found to be a small quantity of sharp shingle, along with two or three gallons of hot water. The time occupied in cleansing ordinary dirty casks is about five minutes. The author further states that he had found super-heated steam an excellent purifier of both new and old casks.

On Improvements in Waggons and Gun-Carriages. By GEORGE FAWCUS.

The author remarked that, during the present year, two serious accidents have happened from want of proper precautions when going down hill with heavy loads, namely, the fire-engine at Sydenham and the boiler-waggon at Preston in Lancashire. The plan now proposed is to combine a check to the tendency to run down hill when ascending or descending an incline road by a pawl acting on a pawl rim or toothed wheel on the inner naves or axles of the wheels. The teeth of the pawl wheels are directed inwards towards the centre of the waggon. When *ascending*, by dropping the pawl on the front wheels they travel forward, *but cannot run back*. In *descending*, the hinder wheels, when pawled, *cannot run down hill*, but act as drags. This arrangement of pawls, &c., holds good if the waggon is intended to travel either end first without turning round. The pawls, &c., may also be applied to single or two-wheeled carts to prevent them running back when going up hill. Two single carts, thus fitted, and placed back to back, would form a good waggon. Applied to field-guns, the pawls would check the recoil of guns when firing, and the limber and gun-carriage wheels would act as one waggon. The suggestions of the author were illustrated by a model of a pontoon carriage, the wheels of which were fitted with pawls in the manner described.

On a New Method of Constructing Boats. By GEORGE FAWCUS.

The National Lifeboat Institution has done much to promote and encourage the preservation of life from shipwreck. The useful services of the lifeboats are limited to certain localities. After every due compliance with the requirements of the legislature, intended to provide every passenger-vessel from our shores with its own lifeboat, a passenger-vessel may yet be provided very inadequately with boats. Ships' boats are very liable to be injured, and, when very large or heavy, are difficult to launch, and in moments of danger and confusion the difficulty is increased. With the proposed plan of boats, a passenger, emigrant, or troop-ship may easily carry sufficient boats for landing all on board at once, without more (perhaps with less) encroachment on the limited space on deck; and her boats, when packed as proposed, will mutually strengthen and protect each other from injury. The use of a large number of smaller or medium-sized boats which may

thus be adopted will lessen the difficulty of launching; and there will then be less confusion by these boats being unencumbered, more promptly loaded and despatched from the ship's side—a place of danger in bad weather, with the passengers more divided. There will then be less danger of rushing to the best or first boat, when every one on board is satisfied that there is room enough in the boats for all, and that all are equally good.

The boats are so constructed that any number will fit one within the other, as internal projections are dispensed with and thwarts folded. Flat, half-round, or angle iron or iron plates are used to impart the necessary strength. Although the inventor prefers to form the boat with two bows, they may yet be made with a bow and stern. These boats are, moreover, admirably adapted for pontoon purposes, as the displacement of each boat is equal to that of a pontoon; and half-a-dozen boats, with the displacement of six pontoons, may be packed in the space of one pontoon.

Remarks on Armour-Plating for Ships. By Captain Douglas Galton, *F.R.S.*

After referring to the experiments on the *Warrior* target, the author remarked: The most severe test to which any target has been subjected at Shoeburyness is far less severe than the ordeal which ships would have to withstand in defending the entrance of or in forcing a passage into a harbour. At the trial of the *Warrior* target, already referred to, the nature and extent of the test to which it was subjected were as follows:—Twenty-nine rounds in all struck the target, embracing a total weight of 3336 lbs. of metal, propelled by 400 lbs. of powder, and representing an amount of work done in foot-pounds of 62,570,000; of this total, however, 32,392,000 go to the credit of shell and solid shot at low velocities, which are held to be almost innocuous against such targets as the *Warrior*. Of the thirteen rounds of solid shot at high velocities, four only were 68-pounders (and one of these is said to have missed the target), representing work done to the extent of 10,260,000 foot-pounds—about one-sixth of the total work; and, if one round missed, as alleged, one-eighth. Thus, three out of the twenty-nine rounds go to the credit of the old 68-pounder, which is said to be the most effective gun in the service against iron plates. Of the twenty-nine rounds not more than five or six were fired in salvo, and yet the plates were deeply indented, buckled, and badly fractured, and many of the fastening-bolts were broken; so that, had the target been part of the side of a ship rolling on the sea, the plates would probably have fallen off in consequence of the destruction of the fastenings. But the strain in such a test as this is far less than that from a well-concentrated broadside, such as the crew of every French ship is regularly exercised to give. The arrangement required for the armour-plating of a ship is a strong front plate, in which deflection under blows shall be prevented, but which shall have some cushion behind to prevent the full concussion of the blow being communicated to the side of the ship. The best form to distribute material in a beam, so as to prevent deflection, is to obtain depth; hence, in tubular girders, the top and bottom flanges are separated by a comparatively light web. Without exactly comparing the effects of the blow of a shot to the weight of a beam, it is apparent that as the best form in which to place the material to resist shot is that which will allow of the smallest yielding at the point of impact, it follows that, after reserving a sufficient face of metal for the front plate, the remainder should be placed in that shape which is resorted to for obtaining stiffness in beams. The author then described the target invented by Mr. Chalmers.

On Air-Engines and an Air-compressing Apparatus.
By J. Jameson, *Close Engine-Works, Newcastle-on-Tyne.*

The author pointed out that in the steam-engine not more than one-seventh of the total consumption of heat was utilized, and then proceeded to enumerate the causes of the non-success of the air-engines which have hitherto appeared, referring to two as types of the whole. In the first he showed that, in addition to the heat required to work the engine, there was a consumption of heat in the hot chambers of the generators, resulting only in the development of heat in the cold chambers, which actually resisted the action of the engine; that this absorption and

development of heat acted injuriously in three ways: firstly, its absorption in the hot chamber diminished the working pressure; next, its development in the cold chamber increased the resistance; and, thirdly, in interfering with the action of the respirator. He also stated that the mechanical necessity existing for keeping all parts of the machine at once in motion, producing excessive cushioning, resulted in a loss of effect, represented by from two to four cubic feet of air for every foot of air contained in the working cylinder at the best point of its stroke; and he said that the operation of these causes necessitated the employment of excessive heat or very slow speed—an almost fatal alternative. The second type of air-engine, he said, required the employment of extremely large apparatus, because there was a pressure-diagram and a resistance-diagram caused by the working of a pump, and the total diagram must always, therefore, amount to three times the effective diagram. In the air-compressing apparatus he described, he pointed out how these defects were obviated:—That there was no necessary transference of heat from the hot to the cold chambers, but that the total heat absorbed in the hot chamber was converted into mechanical effect, and therefore a lower degree of heat might be employed. That there was no difficulty in the arrangement from cushioning in the working cylinder. That the highest point of pressure obtained in the generator was not again lost, as it was in all other cases; and that, in addition to the improvements effected on the first type of engine he described, the new apparatus was capable of receiving the whole effect obtainable by the use of the second form of apparatus without its resistance, and at high instead of low pressures. He finally referred to the advantages to be derived from the use of air instead of steam, which he stated to be a saving of fuel, freedom from risk of explosion, bursting under air-pressure being comparatively harmless, if it should occur; but he stated that no safety-valves were required in the apparatus described by him, as it was self-governing in the production of pressure. It was not liable to derangement. It would work reversed as well as forward. Insurance was not affected by the use of the engine; and the compressed air might be applied in any situation, being laid on like gas, to be used when and how it was required.

On Extinguishing Fires. *By* C. B. King.

The subject, he remarked at the outset, was one of grave importance, touching, as it does, the safety of our lives and our property. In large manufacturing towns and cities, where immense wealth, in the shape of merchandise, is closely packed and stored, the importance of an improved construction of fire-proof warehouses cannot be overrated. It was the object of this paper to give in a succinct form a few facts collected from practical experience. After referring to the importance of carefulness, and remarking that though buildings could not be made wholly fire-proof, they could be constructed with a view of rendering them impervious to fire, viz. to resist, not to assist, any fire that may break out upon their floors, the author described certain fire-proof buildings, and noticed the mode of applying water to extinguish fires. The best means of arresting fires, he observed, was a very wide question, as the only limit to the means was the expense. On the Continent, generally, the whole was managed by Government, and the firemen were placed under martial law, the inhabitants being compelled to work the engines. In extinguishing fires of any magnitude, the steam fire-engine must ever hold the foremost place, not only on account of the development of power, but on the more important score of economy. Having alluded to the first steam fire-engine constructed in England by Mr. John Braithwaite, in the year 1830, and the taking up of the subject by the Americans subsequently, he described the main features of the engines constructed by different companies, and stated that Messrs. Merryweather and Son were now manufacturing steam fire-engines, and had succeeded in bringing out two very good serviceable engines, named the 'Deluge' and the 'Torrent.' He next gave a description of steam fire-engines used for service in the water, and concluded by expressing a hope that the discussion of the subject might bring to light features which had been hidden from the public generally, and increase to greater efficiency the present arrangements for the suppression of fires in many of our large towns and cities.

The Newcastle and Gateshead Water-Works. *By* D. D. Main.

The Newcastle and Gateshead Water-Works, as originally constructed in 1848, consisted of five large reservoirs formed in the valley of Whittle Burn, about twelve miles north-west of Newcastle-upon-Tyne. The drainage-area was about 4340 acres, the capacity of the reservoirs 215,000,000 gallons, and the pipe to convey the water to Newcastle was two feet in diameter, and capable of carrying from four and a half to five million gallons per day. The amount of rainfall was ascertained to be twenty-four inches per annum; and it was assumed that as, in a district of an ordinary character, one-third of the rainfall finds its way into the rivers, in a peculiar locality like Whittle Dean, where the declivities were rapid, the ground impervious, and vegetation scanty, the proportion of water which would be carried off by the natural channels of the country could not be taken at less than one-half. Twelve inches of rain over an area of 4340 acres would have produced 3,250,000 gallons per day; and as the consumption was then only 700,000 gallons per day, and the reservoirs were laid out to contain ten months' supply, it did appear to the promoters that the works were of sufficient magnitude for many years to come, and that ample provision had been made against the longest drought ever likely to happen. The works were brought into operation in October 1848, and were found sufficient until the year 1850. The consumption had in the meantime increased to one and a half million gallons per day, and the number of persons supplied with water from 10,275 in 1845 to 62,740 at the end of 1849. The reservoirs could then only hold a supply for about five months. In the middle of February 1850 a drought commenced, which lasted till the end of October, during which the stored water went continually down; and the company were obliged before the end of summer to have recourse to the works which they had purchased of the previous company, and to pump from the river Tyne in aid of the supply from the reservoirs. It was found that, instead of the rainfall being 24 inches that year, it was only 17·68 inches; and instead of the available quantity being 12 inches, the water actually impounded only amounted to $6\frac{1}{4}$ inches. But it was also discovered that the rain available for water-works falls almost entirely in the winter months, and that to take full advantage of the collecting-ground the reservoirs should be of such magnitude as to impound all that falls, it being unsafe to depend on the summer rains, which, unless they are heavy and continued, are quickly absorbed by the land. After very dry weather it is not unusual for rain to fall to the depth of an inch, and none find its way to the streams. But in a district like this, where the rainfall is so limited, and droughts extending to six and eight months are of frequent occurrence, even great storage-capacity is not to be relied on. The original capital of the company, £200,000, has since been more than doubled; the reservoir-storage has been increased from 215 to 530 million gallons, and the drainage-area from 4340 to 17,300 acres. In the last Session of Parliament power was obtained to supply the water of the River Tyne for manufacturing purposes, and to construct a large impounding reservoir of 500 to 600 million gallons, gaugings having been previously taken which showed that in ordinary years that additional quantity could be obtained from the company's present streams. When the company commenced operations in 1845, the quantity consumed was 700,000 gallons per day, and the system of supply intermittent and irregular; but in their first Act of Parliament they voluntarily bound themselves to give constant service and unlimited supply. At that time the lowest rate for water was ten shilings per annum, a scale of charge which prohibited the poor from having it in their houses at all; and the custom was to carry it from the street pants or fountains, where it was retailed at a farthing per skeel of three gallons. By the present company these pants were gradually abolished; the charge to a poor person occupying a single room was fixed at five shillings per annum, and where houses were let in several tenements, which is the case to a great extent in this town, and the tenants could be supplied at one common tap, the company was at the entire expense of the exterior and interior pipes and fittings. By these measures the supply was greatly extended; and the company may now be said to supply the whole population where their pipes are laid, amounting to about 165,000. The gross daily supply is 4,700,000, or about 28 gallons per head, one-fourth of which is consumed by railways, manufactories, and for trade purposes generally, leaving 21 gallons per

head for domestic consumption. In 1854 the water in the reservoirs was tested for hardness by Dr. Smith, of Manchester, and found to be 13·2 degrees. The water has also been analyzed by different analytical chemists, and found to be composed of the following ingredients:—

	Dr. Smith, March 1854.	Dr. Letheby, February 1863.
Carbonate of lime and magnesia	6·54	13·01
Sulphate of lime	6·13	4·65
Alkaline chloride	4·23	1·63
Oxide of iron and silica	·81	·83
Organic matter	2·38	1·21
Total solid contents in grains per imperial gallon................	20·09	21·33

Analysis of Tyne Water.

	Dr. Letheby, Feb. 1863.	Dr. Richardson, May 1863.	Mr. Pattinson, Jan. 1863.
Carbonate of lime.............	....	....	....
Carbonate of lime and magnesia..	4·09	3·06	4·50
Sulphate of lime	2·49	1·22	·82
Alkaline chloride	1·22	·87	1·65
Oxide of iron and silica	·41	·50	·58
Organic matter	1·39	2·63	2·05
Total solid contents in grains per imperial gallon	9·60	8·28	9·60

It only remains to mention the system of supply. The reservoirs at Whittle Dean are 360 feet above high-water mark of the Tyne at Newcastle, but, on account of the friction along the twelve miles of main pipe, the water does not reach by gravitation the houses in the highest parts of the town. About one-fifth of the whole has to be pumped to these high districts, and for that purpose the company have a fifty-horse-power engine at Benwell reservoir, whence the water is forced to a reservoir at Benwell Bank top, 400 feet above high-water mark, which commands the most elevated houses in the town and suburbs.

The Abbé Moigno explained the action of Caselli's auto-telegraph, now actually at work between Paris and Marseilles, by means of which a fac-simile of the writing of the message is transmitted; and he exhibited specimens of handwriting, portraits, &c., thus effected.

The Abbé Moigno exhibited a model and gave explanations of Messrs. Bourdon and Saleron's apparatus, termed "Injecteur pour les Corps Solides."

The Abbé Moigno exhibited and gave explanations of the "Ventilateur à Réaction" of M. Perigault de Rennes, and of the "Balance Aërostatique" of M. Seiler.

On Bridge Foundations. By T. Page.

The object of the author was to show the system pursued by him without the heavy cost of coffer-dams. The system adopted by the author consists in the use of cylinders of iron filled with brickwork or concrete. The foundation, he said, might be described as a part of a structure, which resisted the weight of the superstructure; and it was evident that the higher the horizontal plane of the resisting

mass was, the less was the weight of the superstructure upon it, and the better adapted as a foundation to resist its pressure. He then described the system he had pursued in the construction of four bridges over the Thames, and also of the pier at Greenock. He considered it important that the foundation of each pier should be one undivided structure; that it should not be broken into separate parts, as it was in cases where cylinders were used; and that, besides the resistance due to the horizontal area of the foundation, it should embrace the additional resistance afforded by the friction due to the vertical surface of the pile; and this, short of founding on rock itself, would present the most solid resisting mass that could be found. The system afforded great facility and rapidity of construction, and its application to harbours of refuge was a subject of great interest and importance at the present time, both for expedition in completing the works and for economy.

New Plan for Hanging Dock-Gates. By R. A. Peacock, *C.E., of Jersey.*

The works of docks and harbours must necessarily be strong and durable, and therefore expensive; but any new methods of construction which are sufficiently durable and convenient, and by which expense is considerably reduced, are so much gained (he exhibited models of gates, showing how the mortices and tenons were immovable). Shipping having gradually but largely increased in dimensions during the last twenty years, it became necessary to provide wider and deeper waterways to docks, and consequently dock-gates of greater height and length. Rollers for the outer ends of the gates to travel upon, by means of tramways at the bottom of the water, were apparently thought indispensable. These tramways, being below the level of the sill of the lock, necessarily became more or less covered with mud, sand, &c., and were, as a matter of fact, so difficult to open and shut with suitable expedition, as to render necessary the very valuable but at the same time very costly hydraulic apparatus now in use. The question is, Can gates be so constructed as to carry themselves without rollers, and so as to save a large portion of their first cost, and the whole of the heavy first cost and annual expense of hydraulic power? After mentioning a number of inconveniences incident to the present system of dock-gates, he went on to say—To prevent all these inconveniences, why not treat the dock-gate like an ordinary field-gate?—make all its parts strong in proportion to its weight, which, in the present case, is about 45 tons; make it carry itself, and so dispense with rollers and tramways. He then proceeded to describe, first, the girder and its fastenings, which are to carry our dock-gate as a gate-post carries its field-gate, and then the suspended gate from the girder. He then remarked that this is clearly an advantage over gates of the usual system, where the pivot is at the bottom, and inaccessible on account of the weight of the gate, and also on account of the mud and the water: the bottom of the heel-post fits into a strong cast-iron shoe. He then referred to the construction of the gate, so as to secure sufficient rapidity and enable the gate to carry itself without the use of rollers; and having described the minor details of the gate, went on to show the immobility of the tenons and mortices. He stated that four lockmen could work two pairs of these gates at a cost for wages of only about £200 per annum, and the heavy cost of hydraulic power is got rid of altogether.

Description of the Large Gyroscope used by Sir William Armstrong *in his investigations on Rifled Projectiles. By* Professor William Pole, *F.R.S.*

At an early period of these investigations Sir William perceived that the motion of a rifle ball had considerable analogy with that of the spinner of the gyroscope; but, as the instruments usually sold under that name were imperfect, he contrived a much larger and better form of the machine, which enabled him to study more satisfactorily the nature of its motion, and more particularly to ascertain accurately the numerical value of the various elements entering into its calculation. Mr. Pole had, at the time referred to, been requested by Sir William Armstrong to undertake the theoretical investigation of the action of the machine. He produced and worked the instrument, and gave a general exposition of its principles, and of the formulæ referring to it; and he finally showed its application to explain some facts in gunnery.

Richards's *Indicator for Steam Engines.* *By* C. T. PORTER.

This instrument (invented by Mr. Charles B. Richards, an engineer of Hartford, Connecticut, U. S.) is constructed on a plan by which it is found that the errors in the motion of the paper and those in the motion of the pencil are quite avoided, and correct diagrams are obtained under all circumstances. The principal distinguishing features of this instrument are a short and strong spring, a short motion of piston, and light reciprocating parts, combined with a considerable area of cylinder, and an arrangement of levers and a parallel motion for multiplying the motion of the piston in such a manner that the diagram is described in the usual way and of the ordinary size. The proportion between the motion of the piston and that of the pencil is a matter of discretion; that which has been adopted is 1 to 4, and the steadiness with which the indication is drawn by these instruments, even at the highest speeds of piston, leaves nothing to be desired.

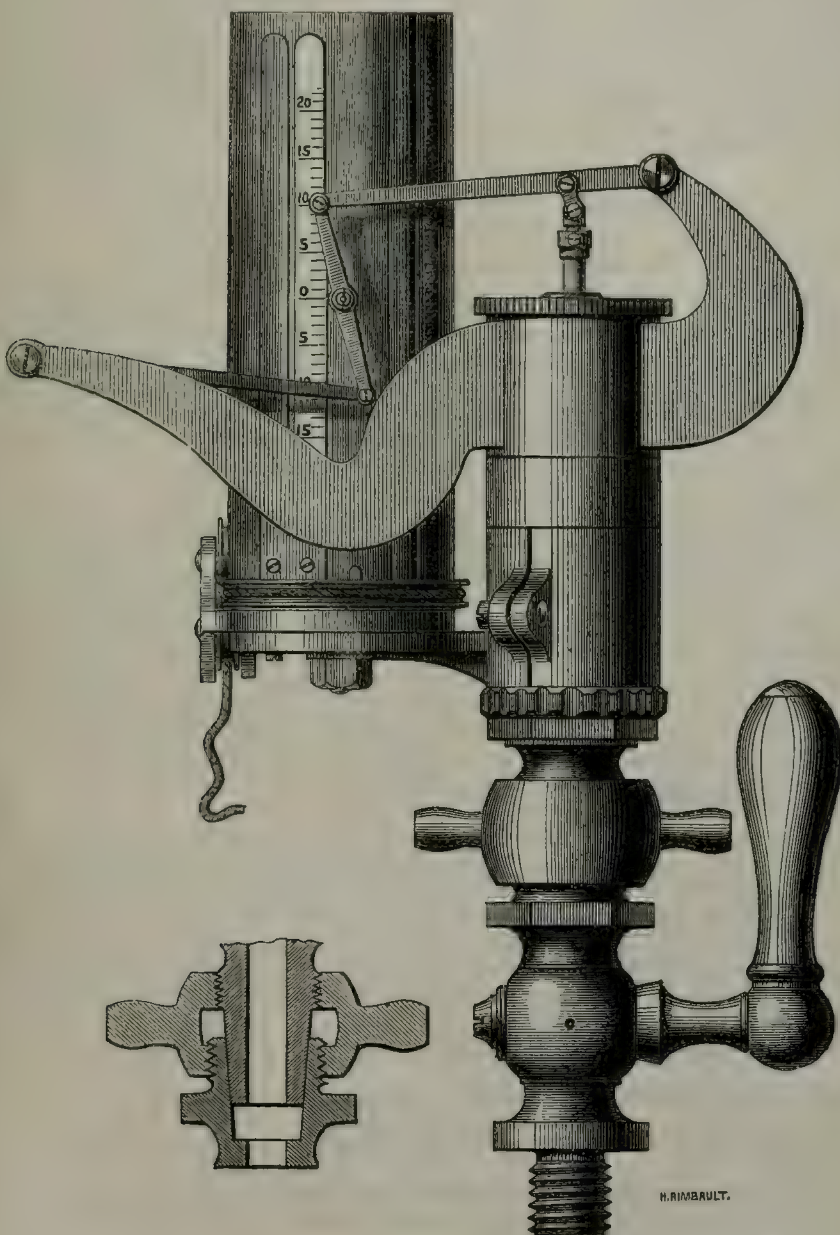
In respect to the ability of these indicators to give diagrams which shall be *perfectly accurate*, it is to be observed that the spring moves without any tendency to bend, and the motion of the piston, and the length of cylinder to be filled with steam as the piston rises, are one-fourth of those in the ordinary indicator. It is assumed, also, that if the motion could be frictionless, then the approach to simultaneousness in the action of an indicator would be in a direct ratio to the strength of the counteracting forces, existing in the pressure of the steam on the one side of the piston and the resistance of the spring on the other, and in an inverse ratio to the distance through which the piston has to move upon any given disturbance of their equilibrium. But, moreover, the motion cannot be absolutely frictionless; and if the friction should be equal in two indicators of different strokes, then the resistance from it, in each one, would be in proportion to the length of its stroke; and if the resistance from friction should be equal in two indicators having different areas of piston, then its effect on the diagrams given by them would be in an inverse ratio to the areas of the pistons. In every view which can be taken, it is evident that the features embodied in this indicator—namely, a strong spring, short motion of piston, and light moving of parts, combined with a reasonably large area of cylinder—are essential for the attainment of truth in the diagram.

General Construction of the Indicator.—The parallel motion is made as compact as possible. For this purpose, a lever of the third order is employed to multiply the motion, and the extremities of the line drawn by the pencil are permitted to have a slight curvature, which considerably reduces the length of the rods, and does not affect the usefulness of the instrument, the curvature at the lower end being below any attainable vacuum, while the extremity of the scale above is very rarely employed.

The indicators are made of a uniform size; the area of the cylinder is one-half of a square inch, its diameter being ·7979 of an inch. The piston is not fitted quite steam-tight, but is permitted to leak a little; this renders its action more nearly frictionless, and does not at all affect the pressure on either side of it. The motion of the piston is $\frac{25}{32}$ of an inch, and the motion of the pencil, or extreme height of the diagram, is $3\frac{1}{8}$ inches. The paper cylinder is 2 inches in diameter; and the length of the diagram may be $5\frac{1}{4}$ inches, if this extent of motion is given to the cord. The diagram is drawn by a pointed brass wire on metallic paper. This is a great improvement over the pencil; the point lasts a long time, cannot be broken off, and is readily sharpened, and the diagram is indelible. The steam-passage has two or three times the area usually given to it. The stem of the indicator is conical, and fits in a corresponding seat in the stop-cock, where it is held by a peculiar coupling, shown in section in the accompanying woodcut illustration of the indicator. This arrangement permits the indicator to be turned round, so as to stand in any desired position, when, the coupling being turned forward, the difference in the pitch of the screws draws the cone firmly into its seat; and when the coupling is turned backward, the cone is by the same means started from its seat. The leading pulleys may be turned by some pressure, to give any desired direction to the cord, and will remain where they are set. By these means the indicator can be readily attached in almost any situation.

In order to adapt this indicator for use on engines of every class, the springs are made for it to nine different scales, as follows:—

No. 1.	$\frac{1}{6}$-inch motion shows 1 lb. pressure on the square inch; indicates from	−15 to + 10
" 2.	$\frac{1}{12}$ " " " " "	−15 " + 22·5
" 3.	$\frac{1}{16}$ " " " " "	−15 " + 35
" 4.	$\frac{1}{24}$ " " " " "	−15 " + 60
" 5.	$\frac{1}{24}$ " " " "	Atmosphere to + 75
" 6.	$\frac{1}{32}$ " " " " "	" + 100
" 7.	$\frac{1}{40}$ " " " " "	" + 125
" 8.	$\frac{1}{48}$ " " " " "	" + 150
" 9.	$\frac{1}{56}$ " " " " "	" + 175



Each of these springs will fit every instrument alike. All of the scales except No. 2 are multiples of 8; and the common rule will measure all the diagrams, if the proper scale is not at hand. It will be observed that the five higher scales do not indicate the vacuum, as the greater number of engines which work steam at high pressures do not condense, and, moreover, at these pressures the scale of the indication necessarily becomes small, while it is always highly desirable to show the vacuum on a large scale. Spring No. 1 may be employed to indicate the vacuum in engines which work steam at high pressures and with condensation. It can be readily substituted in the indicator, and the diagram which it will give will be on a satisfactory scale. It is provided with a stop, which prevents it from being compressed too much, so that a high pressure of steam will not injure it. Moreover, the vacuum being omitted from the scales which go above 60 lbs., the entire range of the pencil is available for the pressures above the atmosphere, which are therefore shown on a somewhat larger scale. The springs indicating pressures above 60 lbs. will be made, however, to indicate the vacuum also, when so ordered.

The springs are tested with a highly sensitive apparatus, expressly designed for the purpose, and are corrected for a temperature of 212°, which is the temperature at which they will work under almost all circumstances, and at which their accuracy is guaranteed.

Thompson's Universal Stopper for Bottles, &c. *By* D. Puseley.

An Investigation on Plane Water-lines.
By W. J. Macquorn Rankine, *C.E., LL.D., F.R.SS.L. & E., &c.*

1. This paper contains an abstract of a mathematical investigation which has been communicated in detail to the Royal Society (see Phil. Trans. 1864). By the term "plane water-line" is meant one of those curves which a particle of a liquid describes in flowing past a solid body, when such flow takes place in plane layers. Such curves are suitable for the water-lines of a ship; for during the motion of a well-formed ship, the vertical displacements of the particles of water near the surface are small compared with the dimensions of the ship*.

2. The author refers to the researches of Professor Stokes (Camb. Trans. 1842) "On the Steady Motion of an Incompressible Fluid," and of Professor William Thomson (made in 1858, but not yet published), as containing the demonstration of the general principles of the flow of a liquid past a solid body †.

3. Every figure of a solid, past which a liquid is capable of flowing smoothly, generates an endless series of water-lines which become sharper in their forms as they are more distant from the primitive water-line of the solid. The only exact water-lines whose forms have hitherto been completely investigated are those generated by the cylinder in two dimensions, and by the sphere in three dimensions. In addition to what is already known of these lines, the author points out that when a cylinder moves through still water, the orbit of each particle of water is one loop of an elastic curve.

4. The profiles of waves have been used with success in practice as water-lines for ships, first by Mr. Scott Russell (for the explanation of whose system the author refers to the 'Transactions of the Institution of Naval Architects' for 1860–62), and afterwards by others. As to the frictional resistance of vessels having such lines, the author refers to his own papers—one read to the British Association in 1861 and printed in various engineering journals, and another read to the Royal Society in 1862 and printed in the Philosophical Transactions ‡.

5. The author proceeds to investigate and explain the properties of a class of water-lines comprising an endless variety of forms and proportions. In each series

* As water-line curves have at present no single word to designate them in mathematical language, it is proposed to call them *Neoïds*, from *νηὸς*, the Ionic genitive of *ναῦς*.

† See also a paper by Dr. Hoppe, in the 'Quarterly Journal of Mathematics' for March 1856.

‡ See also a paper by the author on the Computation of the Probable Engine-power and Speed of proposed Ships, in the Transactions of the Institution of Naval Architects for 1864; also a treatise on "Ship-building," 1864.

of such lines the primitive water-line is a particular sort of oval characterized by this property—that the ordinate at any point of the oval is proportional to the angle between two lines drawn from that point to two foci. (In fig. 1 of the Plate illustrating the author's paper in Phil. Trans. 1864 (not yet published), L B represents a quadrant of such an oval, O being its centre, and A one of the foci; the other focus is at an equal distance from the other side of the centre.) Ovals of this class differ from ellipses in being considerably fuller at the ends and flatter at the sides.

6. The length of the oval may bear any proportion to its breadth, from equality (when the oval becomes a circle) to infinity. (In the Plate referred to above, the length O L is to the breadth O B nearly as 17 : 6.)

7. Each oval generates an endless series of water-lines, which become sharper in figure as they are further from the oval *. In each of those derived lines, the excess of the ordinate at a given point above a certain minimum value is proportional to the angle between a pair of lines drawn from that point to the two foci.

8. There is thus an endless series of ovals, each generating an endless series of water-lines; and amongst those figures a continuous or "fair" curve can always be found, combining any proportion of length to breadth from equality to infinity, with any degree of fulness or fineness of entrance, from absolute bluffness to a knife-edge.

9. The lines thus obtained present striking likenesses to those at which naval architects have arrived through practical experience; and every successful model in existing vessels can be closely imitated by means of them, from a Dutch galliot to a racing-boat.

10. Any series of water-lines, including the primitive oval, are easily and quickly constructed with the ruler and compasses as follows. Parallel to the longitudinal axis OX, draw a series of straight lines at equal distances apart. Through the foci draw a series of circular arcs AC_1, AC_2, &c., so as to contain a series of angles found by dividing those distances by

$$\frac{OL^2 - OA^2}{2OA}.$$

Each of those circular arcs indicates the direction of motion in still water of each of the particles that it traverses. Then through the angles of the network formed by the straight lines and circular arcs draw a series of curves; these will be the required water-lines †.

The centre of curvature of the oval at L is the focus A.

11. The following curves, traversing certain important points in the water-lines, are exactly similar for all water-lines of this class, and are easily and quickly constructed with the compasses.

L M is a hyperbola having a pair of asymptotes crossing the axes at O at angles of 45°. It traverses all the points at which the motion of the particles in still water is at right angles to the water-lines.

L Q N and L P are the two branches of a curve of the fourth order, having a pair of asymptotes which traverse O, making angles of 30° with O X. A straight line joining L and P makes an angle of 30° with L O. The two branches cross the axis O X at L, making angles of 45°. The branch L Q N traverses a series of points, at each of which the velocity of gliding of the particles of water along the water-line is less than at any other point on the same water-line. The branch L P traverses a series of points, at each of which the velocity of gliding is greater than at any other point on the same water-line.

12. The axis O Y from B to P traverses a series of points of minimum velocity of gliding: from P onwards it traverses a series of points of maximum velocity of gliding.

13. Every water-line, complete from bow to stern, which passes within the

* As a convenient and significant name for these water-lines, the term "Oögenous Neoïds" is proposed (from Ὠογενής, *generated from an egg*, or *oval*).

† The first employment of a graphic process of this kind is due, it is believed, to Professor Clerk Maxwell, who applied it to certain curves connected with electricity and magnetism.

point P, has three points of minimum and two of maximum velocity of gliding; while every water-line which passes through or beyond P has only two points of minimum and one of maximum velocity of gliding. Hence the latter class of lines causes less commotion in the water than the former.

14. On the water-line P Q which traverses the point P itself, the velocity of gliding changes more gradually than on any other water-line having the same proportion of length to breadth. Water-lines possessing this character can be constructed with any proportion of length to breadth, from $\sqrt{3}$ (which gives an oval through L and P) to infinity. The finer of those lines are found to be nearly approximated to by wave-lines, but are less hollow at the bow than wave-lines are.

15. The author shows how horizontal water-lines at the bow, drawn according to this system, may be combined with vertical plane lines of motion for the water at the stern, if desired by the naval architect.

16. In this, as in every system of water-lines, a certain relation (according to a principle first pointed out by Mr. Scott Russell) must be preserved between the lengths of the after-body and fore-body and the maximum speed of the ship, in order that the appreciable resistance may be wholly frictional and proportional to the square of the velocity (as the experimental researches of Mr. J. R. Napier and the author have shown it to be in well-formed ships), and may not be augmented by terms increasing as the fourth and higher powers of the velocity through the propagation of diverging waves.

Description of Corrugated Armour of Steel or Iron for Ships of War. *By* GEORGE REDFORD.

The method proposed is founded upon two principles of strength—cohesive strength and mechanical strength. The plates, being made of steel, hardened and tempered as nearly as possible up to the cohesive strength of the Whitworth shot and shell, are of two kinds—one thick and corrugated, the other thinner and plain. The steel corrugated plates, which are 3 inches thick, are placed upon the thinner plates of 1 inch, also tempered, and bolted through the skin of the ship—to the ribs in an iron ship, or to the timbers in a wooden one. If iron plates of the corrugated form were backed with an inch plate of steel, hardened and tempered, the author thought that they would prove impenetrable; and even smooth iron plates of 4 inches, thus laid upon steel, would be more effective than iron plates even of 7 inches thick, backed by timber. The author states that the advantages of the plan proposed are, besides the protection of the ships, the reduction of the weight of armour much below that contemplated for the new ships of war, and below that of the *Warrior*, the *Achilles*, and the *Minotaur*. The saving of at least 1 inch in thickness of plates would give a reduction of 100 tons; and, if it should be found that timber backing can with this armour be dispensed with (a point now so much the subject of inquiry), the reduction of weight would be about 250 tons in a ship of the *Warrior* class. The extra cost would be, to a great extent, met by the saving in the thickness of plates and the timber backing. The author looks to the development of the working of steel, and the conversion of iron into that far stronger metal, for the acquisition of a lighter and impregnable armour for ships of war, a desideratum which can never be obtained by merely increasing the thickness of iron to any extent a ship could carry and be fit for ocean service. The author stated that steel plates of this kind could be manufactured at about one-third more than the cost of the best iron armour-plates.

Rifled Ordnance. *By* G. RICHARDS.

The author suggested and illustrated a *square*-bore gun introduced by him, to give greater initial velocity to projectiles than was attainable by any plan yet proposed, inasmuch as the area of the square bore was at least 20 per cent. more than that of the circular bore containing a shot of the same diameter, thereby exposing, by using a wad or sabot, a greater surface to the impact of the ignited powder. The author also showed a method of loading heavy ordnance (applicable to sea service) by means of a loading-rod. The method of loading the gun was by means of a loading-rod passing through a perforation in the breech of the gun, and thence

to the muzzle. The cartridge used was also made with a perforation, through which the loading-rod passes. The loading-rod was quickly attached to the base of the projectile at the muzzle of the gun. Both rod and charge were quickly drawn into the chamber of the piece, disconnected in readiness for loading, and the breech was then closed by a small apparatus, such as a revolving disk.

On the Paper-Manufactures of Northumberland and Durham. *By* W. H. Richardson.

The author stated that the principal improvements that have been made in the manufacture of paper in late years are in the details and general efficiency of the machinery, whereby a much larger quantity of paper is made with the same apparatus than formerly; and in the superior management of the chemical processes. The introduction of Esparto grass, the importation of which has been steadily increasing, was also noticed: 10,000 tons of this were imported in the year 1862 into the port of Newcastle alone, the greater part of which was forwarded into Scotland, Lancashire, and elsewhere. Esparto, or *alfa*, as it is called on the African coast, is a coarse grass which grows in sandy places in almost all the countries bordering on the Mediterranean, and has been used from time immemorial for making mats, ropes, &c., and has been extensively used for paper-making since 1860, mainly by the exertions of Mr. Thomas Routledge, the patentee of the only successful process. No material alteration in the machinery or apparatus is required for working esparto by this process, and very much less power is required. The successful working of this fibre depends on the careful and proper adjustment of the quantity and strength of the chemicals employed. The quantity of soda ash required for neutralizing the gummo-resinous matters in the fibre, so as to admit of its being made into a pulp, is very large, though not so great as is required for straw; and the fibre, unlike rags, never having before been subjected to bleaching or other chemical treatment, also requires very much more bleach-powder to bring it to a colour suitable for printing-paper. The quantities required are from five to six times as much as for cleansing and bleaching the coarsest rags. Nearly all newspaper, not excepting that on which the *Times* is printed, contains a portion of esparto; and some of the penny daily papers published in Edinburgh contain only one-fourth of rag material. The large supply of paper-making material from this source has been most opportune. Rags are becoming gradually scarcer; coloured rags, suitable for making common printing-paper, were worth 4*s.* to 6*s.* per cwt. in 1848, and are now worth 9*s.* to 12*s.* per cwt., and this notwithstanding the relief produced by the importation of esparto. The scarcity, the existence of which the jurors' report of the Exhibition of 1862 most unaccountably denies, has been aggravated by the almost total cessation of the supply of waste and tares from the cotton-mills; and, even with the assistance of esparto grass and cheaper chemicals and fuels, the paper-makers in this country have been placed by recent legislation in a most disadvantageous position in respect of the supply of material in comparison with their continental rivals.

Note.—Importation of esparto in 1863 into the United Kingdom, 25,161 tons 8 cwt. 1 qr. 12 lbs.

On an Improved Manufacture of Biscuits. *By* J. Robinson.

Reports and Sections relating to Captain B. Pim's *projected Transit Route through Central America, showing the* modus operandi *of Surveying in the Forests of that Country.* *By* E. Salmon, *C.E.*

This report detailed the writer's proceedings in the primeval forests, while making a preliminary survey to prove the practicability of the Interoceanic Railway through Nicaragua. It was accompanied by drawings and sections. Much of the document was occupied with a description of the difficulties successfully encountered by the surveying party, the nature of the country, and their contrivances for obtaining food, water, shelter, &c. The nature of the soil and the plants of the district were described at length. In a second expedition, subsequently undertaken, the party encountered great obstacles from the advanced

state of the rainy season. In conclusion, Mr. Salmon remarked, "I have no hesitation in stating that, as far as my portion of the work is concerned, no real engineering difficulty exists, and I see no reason to think that the proposed railway would be an expensive one to make. I have gone largely into the question of labour, and I find that you can get as many men as you require—first-rate workmen—at the rate of 15 to 20 dollars per month, besides their food. These questions, however, cannot be entered into in a brief outline like the present one. In conclusion, it may be interesting to state that on my first expedition, with a gang of two Creoles and twelve Indians (total party fifteen), I cut through the dense jungle, $20\frac{1}{4}$ miles, in 24 working days—average per day rather more than $\frac{5}{6}$ths of a mile. On the second expedition, with a gang of eight Creoles and six Indians (total party fifteen), I also cut $22\frac{1}{4}$ miles in $20\frac{1}{2}$ working days—average 1 mile and 5 chains per day, making a total of $42\frac{1}{2}$ miles in $44\frac{1}{2}$ working days—average of both expeditions rather more than 58 chains per day.

Portable Machinery or Apparatus for Riveting, Chipping, &c., the invention of Mr. J. M'Farlane Gray, *of Liverpool. By* W. Smith, *C.E.*

The special feature in the instruments or apparatus under notice is as follows, viz., that whether used for riveting, caulking, chipping, or otherwise operating upon and treating metals or other substances, by means of a series of blows, the principle of the construction and action of the several varieties of instruments is the same. The piston, plunger, bolt, or striker traverses the cylinder independently of the "tool-head" or "tool-holder," or of the operating tool, and through a greater distance, and moreover does not pass out of the steam-cylinder, but gives the blow, or series of blows, "shuttle-like" *within* the cylinder upon the "tool-holder" or "tool-head," which is free to slide backward and forward within one end of the steam-cylinder; and the change of motion, or the rapidity of action, of the moving part or parts within the cylinder is effected by inside tappets, or the combined action of a tappet or tappets and a steam-piston valve. The outer form of such instruments, and the arrangement and combination of their parts, have of course to be varied to suit the special purpose for which they are intended to be used.

In every case the cylinder is provided with a bolt, piston, or plunger, capable of traversing backward and forward upon the admission of steam in either direction. This moving part has sufficient weight to enable it to accumulate the *vis viva* due to almost the full pressure of the steam upon its end surface, or area, and by its impact to give out this force upon the rivet, or other surface operated upon, through the intervention of a "tool-head" or "tool-holder."

For the admission of steam to the slide-valve chest of the cylinder, it is preferred to used a small gridiron valve, which may be kept close by a spring, and is opened by means of pressure on a thumb-piece or lever. The gridiron slide-valves, having back and front sliding faces alike, are in equilibrium. A cock or any other suitable valve contrivance may, however, be substituted.

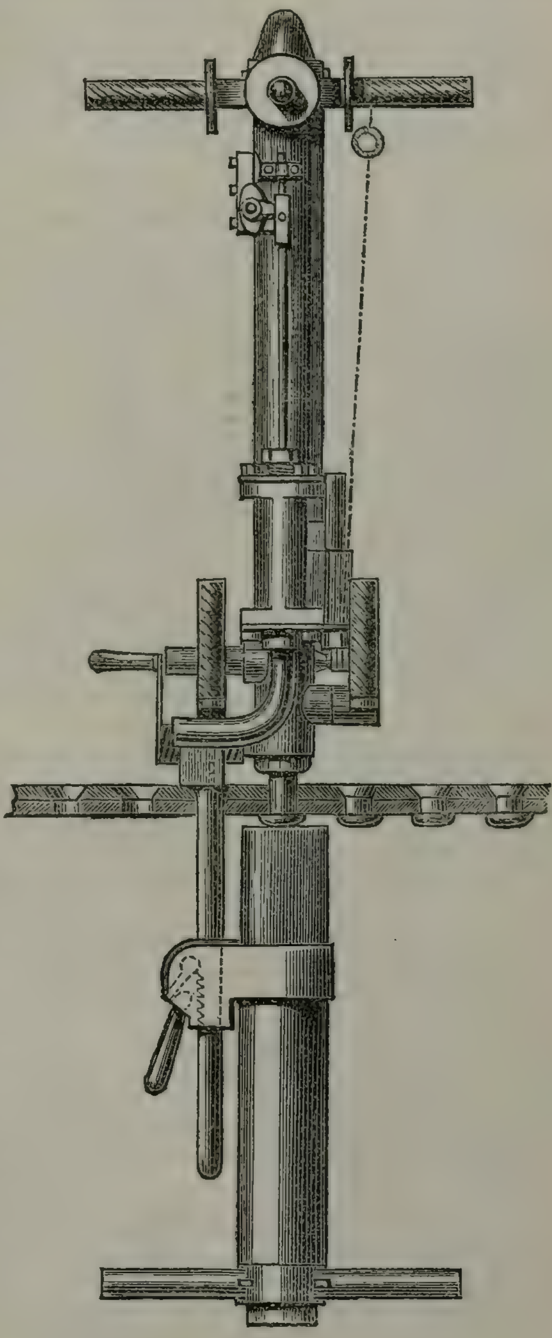
The steam is conveyed from the boiler to the apparatus by means of a flexible pipe, or by metal tubing and flexible pipe combined. The exhaust-nozzle may be on the middle of the valve-chest cover, and have a short elbow or other form of pipe to direct the exhaust steam from the operator, and is under the control of the person using the apparatus; but a stud or stop-pin may be inserted through the cylinder and the gland, to prevent the chipper or the tool-head being driven out; and also a spiral or other reacting spring should be introduced, for the purpose of overcoming the friction between the tool-head or holder and the gland and the stuffing-box, and thus return the chipping or other tool, or the tool-head or tool-holder, after each blow, back to its normal position.

The tool-head may be itself the operating tool, or it may be a socket to contain the tool required; but, whatever its form may be, and whether brought back by a spring or not, its travel or motion backward and forward, or in and out, is in every case less than that of the piston, bolt, or striker.

This apparatus, when designed as a "riveter," is provided with suitable handles, for the purpose of holding and guiding the apparatus while it is in operation, and also with handles whereby to lift it from one position of the work to another.

Instead of depending upon the operator for supporting and guiding the apparatus, it may be mounted upon a guide-bar or other form of carriage. The operator may also be assisted by sustaining part of the weight of the apparatus by a rope or chain.

For riveting rows of holes at regular intervals, a stud-hook may be fitted so as to project in front of the machine, and, by entering an adjacent or advance hole, assist in supporting, as well as in guiding, the apparatus whilst in use. This stud-hook may be moved by a regulating screw, to adapt it for any required pitch of holes. Where it can be applied, a spring gauge-pin is adopted, forming at the same time a pin to gauge the pitch of the holes, and by locking into a spring-box, which contains a spring-dolly or "holder-up," and being forced on the pin with considerable pressure, it becomes a supporting bolster for the rivet-head, and forms a mechanical "holder-up." The pin which enters the rivet-hole may be attached to the riveting-cylinder with a moveable screw, and it may be cut as a ratchet, and lock into a spring-pall; or the arrangement may be reversed, as the dolly spring-box or the spring-pin may be attached to the spring-box, and the socket and pall to the cylinder.



The accompanying woodcut illustrates one arrangement of this apparatus when used for the purposes of riveting.

In operating with the "steam-chipper," the apparatus being provided with suitable handles, the operator grasping them brings the apparatus up to the surface to be chipped; and the steam being admitted, a succession of rapid blows is given, and as the metal is chipped, the operator advances the apparatus. The chipper may be supported on a sliding or other carriage, or by other suitable means.

In heavy work, and where the diameter of cylinder and pressure of steam used are such that the amount of backward pressure of the apparatus would be inconvenient for the operator to support or withstand, a lanyard attached to the cylinder may be carried to some convenient point of attachment, in advance of the machine, so as partly to keep the apparatus

up to its work. Instead of attaching this lanyard to a fixed point, it may run over a pulley, and have a weight hanging from it.

Where found necessary, a strut, arranged with a view to simple adjustment, may be applied to support or guide either the riveters, the chippers, the caulkers, or the hammers, and be substituted for the hand supporting.

Mr. Gray also employs a combined steam-boiler and rivet-hearth, with furnace common to both, to be used in conjunction with the several modifications of the apparatus just described; such combined steam-boiler and rivet-hearth or forge serving the twofold purpose of generating the steam for working such apparatus, and of heating rivets to be operated upon thereby.

In the modification of the apparatus, when mounted and fitted for hammering copper pipes, a saddle-piece of wood is bolted to a flange, the saddle being curved to fit the pipe to be hammered. A balance-weight is also suspended upon the curved arm attached to the apparatus, in order to keep the same erect whilst it is at work operating upon the copper pipe.

Novel Arrangement of Direct-acting Steam Engines. By W. Smith, *C.E.*

This system of direct-acting steam-engines is the invention of Messrs. Jackson and Watkins, engineers, of Millwall, who, instead of employing a guide-block and guides, or any of the usual methods of guiding and supporting the outer end of the piston-rod at its junction with the connecting-rod, and instead also of working a pump by a lever, or from off the crank by an excentric, or other means of communicating motion, effect these two objects of guiding the piston-rod and working the pump by placing the pump-barrel with its longitudinal axis in, or nearly in, a line with the cylinder, and between the cylinder and the crank-shaft, and the pump-plunger or piston is connected to the piston-rod and the end of the connecting-rod of the engine by a fork end or any other suitable means; thus the pump is worked direct, and forms also the guide for the piston-rod. In condensing-engines the air-pump is the pump employed in this manner. The piston or plunger of the pump is of sufficient diameter to allow of a trunk large enough to permit of the connecting-rod vibrating within it; and where the distance between the cylinder end and the crank-shaft is limited, as is generally the case in marine engines, the inventors prefer to employ a single-acting and single trunk-pump, the capacity of the pump-chamber or barrel being regulated by the dimensions of the annular space, or the difference between the exterior diameter of the trunk and the interior diameter of the pump-barrel.

In inverted direct-acting screw engines the valves may be placed at the bottom of each pump in direct communication with the condenser. In every case the connecting-rod works within the trunk of a pump placed between the cylinder of the pump and the packed end or ends thereof; or the piston and the gland alone are the means of guiding the piston-rod, and of taking the thrust due to the angular motion of the connecting-rod. For working the back slide or cut-off slide of double-slide valve engines, it is connected to the backward excentric or its rod directly through a weigh-shaft, or by any other of the well-known means, and the amount of expansion regulated by changing the positions of the slides by means of a screwed valve-rod or other suitable means.

The rod of the main slide-valve and the expansion-valve rod pass through a gland in the slide-chest, and are moved together by the excentric gear; and the expansion-valve rod is not connected to the link-block, but, by means of a rod or bar, to a stud or pin projecting from the face of the backward excentric strap or rod. On the upper end of the valve-chest the rod of the expansion-slide passes through a gland, and has a hand wheel or cross fitted thereon for the purpose of turning it, and thereby changing the position of the expansion-slides or cover-plates in relation to the steam passages or openings through the main slide-valve; the expansion-valve rod is screwed with a right- and left-hand thread, and the lower end of the rod is made to turn or swivel when it is required that the degree of cut-off shall be changed.

In adapting this invention to horizontal or other forms of direct-acting pumping-engines for raising or forcing, or raising and forcing water, a trunk-pump is applied

of suitable dimensions, and placed between the cylinder and the crank as previously described, and for this purpose a double-acting pump with double trunk may, by increasing the length of the piston-rod and the connecting-rod, be employed.

It will be seen from the foregoing description, that by the plan adopted by Messrs. Jackson and Watkins of placing the pump between the cylinder and the crank in direct-acting steam-engines, the usual guide bars and blocks are dispensed with; and that in working the air-pump in direct-acting condensing-engines according to this plan, the necessity no longer exists for the employment of separate and independent levers, beams, connecting-rods, &c.

A novel Method of covering Boilers, Pipes, and Cylinders of Steam Engines for preventing the Radiation of Heat, the invention of Mr. James Spence, *of H.M. Dockyard, Portsmouth. By* W. Smith, *C.E.*

In the non-conducting compositions which Mr. Spence proposes to employ, argillaceous earth is ground or beat up and mixed with water, so as to form a paste, with which is compounded oil-cake, fish- or train-oil, cow-hair, carbonaceous matter, and the other materials afterwards mentioned, for giving consistency, character, or colour, according to the purpose for which the composition is required. The hair is well opened and beaten in or incorporated, and the whole mass is thoroughly mixed until it has obtained the requisite degree of density or consistency.

For coating steam-boilers and such like vessels subject to great heat, and for other similar purposes, argillaceous earth (say, one thousand pounds in weight) is ground or beat up and mixed with water so as to form a paste. To this is added about twenty-four pounds of oil-cake, about three gallons of fish- or train-oil, and to this mixture is introduced about twenty-four pounds of cow-hair, twenty-four pounds of soot, and three pounds of bone-dust or bone-ash. These are thoroughly combined together, and form a plaster or composition capable of being applied in the manner of plastering walls and other surfaces.

For coating steam-pipes, steam-engine cylinders, and other such bodies and surfaces, argillaceous earth (in weight, say, one thousand pounds) is taken and prepared as before; to this is added about thirty pounds of oil-cake, two gallons of fish-oil, about thirty-six pounds of cow-hair, fourteen pounds of soot, eighteen pounds of bone-dust, and fourteen pounds of ground carbonaceous matter; these are well incorporated in a finely divided condition, as before stated. For purposes where a finer quality of coating is required, there may be less oil, less cow-hair and dry matter introduced in proportion to the weight of clay.

For a finishing coat to the previously described compositions, the following substances may be used :—To each one thousand pounds of argillaceous earth about one and a half or two gallons of fish-oil, about thirty-two pounds of oil-cake, thirty-two pounds of cow-hair, about half a gallon of linseed oil, twenty-four pounds of ground charcoal, and about eight pounds of glue; to these may be added about eight pounds of paint or colouring matter, of any colour or tint that may be preferred.

Steam-boilers may be coated whilst in use; and the composition may be applied by hand or trowel to a depth of three-quarters of an inch or so, and scored or grained across and allowed to dry, and then a second or any additional number of coatings may be added.

For coating circular pipes or such like surfaces, a layer of hay or straw bands, saturated in the composition, may be lapped or coiled around the pipe or vessel, the composition plastered on, and the coatings or layers added at intervals. Wood laths may be introduced; and any of the well-known means of bonding or binding may be employed, according to the form of the body to which the composition is to be applied, and according to the nature of the action to which the material is to be subjected.

This process is intended to be used instead of employing felt and wood lagging with sheet-lead covering or other additions, as a covering for steam-boilers, cylinders, pipes, and such like, and other vessels and bodies, for prevention of the radiation of heat, as also for protecting pipes and other vessels containing fluids or liquids against the external action of extreme cold, and generally for coating vessels or

bodies subject to the action of heat or cold, and for preventing radiation therefrom, or the transmission or passage inward or outward of heat or cold.

The method of applying the non-conducting composition to the surface of steam-boilers, cylinders, and other heated surfaces for the prevention of the radiation of heat, as also to water-pipes and other surfaces for preventing the injurious effects of intense cold or frost, must of course vary according to the form or shape of the object to be covered, and the particular purpose for which it is intended to be employed; but, as a rule, the expedients which are usually adopted by plasterers or workmen employed in coating ceilings, walls, and other surfaces with plain or ornamental coatings of plaster or cement may be adopted with advantage in applying the composition according to this invention to various metallic and other bodies. Especial care is to be taken that, after the first coating of the composition has been applied to any heated or other surface, this coating is pricked through in a sufficient number of places in order to allow the air and moisture to escape freely when drying, this being essentially necessary in order to ensure the adhesion of the composition to the surface to be protected.

An improved Valve and Apparatus for Atmospheric Railways. *By* W. Smith, *C.E.*

The object of this contrivance (the invention of the Rev. G. R. Harding, of St. Ann's, Wandsworth) is chiefly to overcome the defects which have attached to the valvular portion of previously tried systems of atmospheric railways, or railways worked by the vacuum or pressure of air. The inventor uses a number of blocks or pieces of material converging towards each other, for the purpose of fitting into the trough or channel in the railway tube, and having also, in relation to the longitudinal axis of the tube and the trough in which the blocks are fitted, angular faces, or fitting and bearing surfaces. A series of these blocks or pieces being jointed together forms the continuous flexible bar or valve. The trough being formed of V-like shape in transverse section, and from the angular arrangement of bearing and fitting surfaces between the blocks or pieces, greater perfection of working condition is ensured; so that the greater the atmospheric pressure, or the better the vacuum, the more perfect contact is obtained between the working parts of the apparatus. The accompanying woodcuts illustrate some of the methods of putting the invention into practice.

Fig. 1.

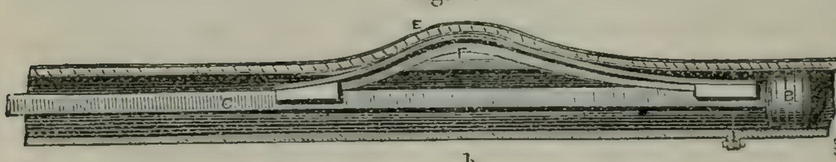


Fig. 2.

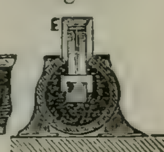


Fig. 3

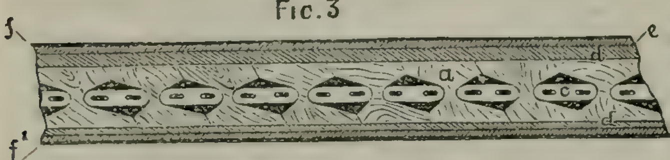


Fig. 4.

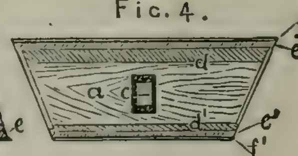


Fig. 1 is a longitudinal section of the tube of an atmospheric railway fitted with the piston, flexible bar or valve, and curved lifting-piece, in accordance with the invention of the patentee. Fig. 2 is a cross section of fig. 1, taken on the dotted line *a*, *b*, showing the tube, part of the flexible bar or valve fitting in the V-shaped trough, the piston-carriage, and the curved lifting-piece.

A is the tube; B, the piston; C, piston-rod; E, the flexible bar or valve; F is the curved lifting-piece.

In figs. 3 and 4 the flexible bar or valve is shown separately and to enlarged scale. The blocks, *a*, composing the valve are hinged together by means of fixed pins, *b*, and slotted links, *c*, so as to counteract any strain, as by this plan the blocks slide upwards and downwards as the case might be, and the links allow the blocks

free play. On the upper and lower surfaces of these blocks a band of india rubber is laid, next to which are bands of leather, and on the outer upper surface is laid a metallic band or any other suitable material to protect the valve from rain or damp, and on the lower surface a thin band of steel, so as to allow it to ride easily upon the curved lifting-piece F. Fig. 4 is a cross section of fig. 3, in which a part of the slotted link, *c*, is shown.

The blocks may, however, be formed of metal or any other convenient material, and be solid or hollow. The bands shown in the illustrations might, when the metal blocks were employed, be replaced by a metallic band, and leather strap on its under side, and screwed on to each of the blocks.

On Self-acting Valve Motion for Steam Hammers. *By* John Sturgeon.

On the Diagonal Principle of Iron Ship-building. *By* R. Taylorson.

In this principle the line of resistance to forces acting in the direction of the vertical planes is diagonal to the circumferential line of the body of the ship, thereby opposing the greatest amount of resistance that could be given at an angle equivalent to the inclination of the planes. Ships built on the diagonal principle were stronger, the author stated, than those on the vertical, at the rate of 100 per cent.

On the Prevention of Fouling of Ships' Bottoms. *By* Dr. White.

The author proposed a composition made of equal parts of powdered quick-lime, of fat, and of oil, mixed and rubbed together. It is laid on the first time, when cold, by means of a short-haired painter's brush, on the surface while high and dry; but when afloat it must be applied by means of a diver's hand. This composition is a kind of soap, which is insoluble in water, and which undergoes a slow chemical change, the result of which is that, after a few months, it becomes rather less soft, and more easily separable in the form of flakes or scales from the submerged surface of the ship than it was when fresh applied. The author has tried a combination of fat and oil, and of fat and white lead, and has determined that the lime-soap is the article best adapted for the purpose. It can be laid on smoothly in the air, and also applied under the water with great facility. From experiments made by Dr. White, he thinks that the capacity for speed of an iron vessel will be increased fourteen per cent. by the use of this soap. The author also proposes that, before the lime-soap is applied, a strip of sheet zinc should be fixed on the upper part of the flat surface of each row of iron plates below the light-load line-mark, by means of iron screws about a quarter of an inch in length, with broad heads, taking care that some part, at least, of the surfaces of contact of the iron and zinc are clean, as shown by the metallic lustre. The surface of the zinc in contact with the iron which is to be protected should be equal to at least one-sixteenth part of the surface of iron to be protected. The zinc corrodes; and therefore it will be necessary from time to time to fix it closely by the screws, and to replace it when necessary, all of which can be done by divers. Aluminium protects iron from corrosion by electro-metallic action, in the same manner as zinc does; but a smaller area of surface of aluminium will have an effect equal to a larger extent of zinc. The higher price of aluminium will probably prevent the use of it for this purpose.

LIST OF PLATES.

List of Papers of which Abstracts have not been received.

On the Newcastle Time Gun. *By* Prof. C. PIAZZI SMYTH, *F.R.S.*

On the Analysis of Chinese Iron. *By* Dr. STEVENSON MACADAM.

On the Manufacture of Superphosphates and Dissolved Bones. *By* Dr. STEVENSON MACADAM.

Recent Applications of the Hydrocarbons derived from Artificial and Natural Sources. *By* Dr. B. H. PAUL, *F.C.S.*

On Coal, Coke, and Coal-mining in Northumberland and Durham. *By* N. WOOD, J. TAYLOR, J. MARLEY, *and* J. W. PEASE.

On the Upper Tertiary Strata of the Bohuslän District. *By* Dr. A. W. MALM.

On some Fish-remains that have occurred in the Coal-measures of Durham and Northumberland. *By* T. ATTHEY *and* J. W. KIRKBY.

On the Cultivation of Cinchona in India. *By* CLEMENTS R. MARKHAM.

Notes on the Homologies of the Trilobites. *By* C. SPENCE BATE, *F.R.S.*

A brief Account of the Vegetation of the Cliffs of Mohir, co. Clare. *By* N. B. WARD, *F.R.S., F.L.S.*

On the Physiological Properties of the Nitrite of Amyle. *By* Dr. B. W. RICHARDSON.

On the Reason why the Stomach is not digested by its own Secretion during Life. *By* Dr. PAVY, *F.R.S.*

On the Renal Organ of the Aplysia. *By* Prof. ROLLESTON, *F.R.S.*

On the Physiological Action of the Uterus in Parturition. *By* Dr. Donkin.

On the Calabar Bean. *By* Thomas Nunneley.

Miners' Safety-mask for supporting Life in Firedamp and other noxious vapour. *By* Dr. B. W. Richardson.

Ethnology of the Island of Formosa.
By Robert Swinhoe, *H.M. Consul at Formosa.*

On the Effects of the recent Gold Discoveries. *By* Henry Fawcett.

On Transportation in connexion with Colonization. *By* Colonel Torrens.

On Regenerative Gas-Furnaces as applied to Iron-Works. *By* C. W. Siemens, *C.E., F.R.S.*

On the Proportions of Ships of least Skin Resistance for a given speed and displacement. *By* Prof. W. J. Macquorn Rankine, *LL.D., F.R.S.*

On the Improvements now being carried on in the River Tyne.
By J. F. Ure.

On Targets for Gunnery Experiments. *By* Captain Douglas Galton, *F.R.S.*

The Application of Machinery to Coal-cutting. *By* Samuel Firth.

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Engineering Manufactures of the Tyne and neighbouring Districts.
By P. Westmacott *and* J. F. Spencer.

New Method of Working Railways by Stationary Engines.
By R. *and* W. Hawthorn.

On the Railways and Locomotives of the Districts adjoining the Rivers Tees, Tyne, and Wear. *By* J. F. Tone.

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REPORTS ON THE STATE OF SCIENCE.

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MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Œconomy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15s.

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16s. 6d.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Œconomical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15s.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Œconomy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Œconomy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s.*

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigo-

nometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores; —Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15s.

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds; —James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{t}{}^{-\alpha} \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\ (\alpha+1)\ (\alpha+2)$ &c....$(\alpha+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry; —John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargrave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20s.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the

internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles' paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15s.

Contents:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq. of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15s.

Contents:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of

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PROCEEDINGS of the THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at £1.*

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